This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

2 45 0172 6311
LANE MEDICAL LIBRARY STANFORD

WOOD'S LIBRARY

OF

STANDARD MEDICAL AUTHORS

LANE

MEDICAL LIBRARY

LEVI COOPER LANE FUND

and is not to be removed from the Library Room by any person or under any pretext whatever.

THE

TREATMENT OF WOUNDS

ITS

PRINCIPLES AND PRACTICE, GENERAL AND SPECIAL

BY

LEWIS S. PILCHER, A.M., M.D.

MEMBER OF THE NEW YORK SURGICAL SOCIETY

LANE MEDICAL LIBRARY
393
SAN FRANCISCO

WITH ONE HUNDRED AND SIXTEEN WOOD ENGRAVINGS

NEW YORK
WILLIAM WOOD & COMPANY
56 & 58 LAFAYETTE PLACE
1883

LANE LIBRARY

COPYRIGHT
WILLIAM WOOD & COMPANY
1888

TROW'S
PRINTING AND BOOKBINDING COMPANY
201–213 *East Twelfth Street*
NEW YORK

WI51
P63
1883

PREFACE.

In the present work I have attempted to state, first, the principles upon which the treatment of wounds should be based; then, to describe the means which are available to the surgeon for satisfying the demands of these principles; and, lastly, to point out the particular modifications which the peculiarities of special wounds may require. In the first part of the work, the physiology of repair, and the character of the influences which are capable of disturbing physiological repair necessarily receive attention. A knowledge of these must form the ground-work of all rational wound-treatment. As the result of the more exact methods of research of recent years, while much chaff, consisting of half truths and incorrectly interpreted observations, has accumulated, some facts have undeniably been established, in the domain of physiology and pathology, which will stand the winnowing process of time and experience, and will remain as permanent truths that will always require the recognition of intelligent students of Nature. Not the least of these are those which have appeared in the special fields of wound-repair and wound-disturbance. These I have endeavored to state in the following pages with an earnest conviction of their truth, and of the great importance attaching to their becoming generally understood and accepted as working-facts.

It is not necessary that one should blindly follow the theories or the methods of any one man; nor, indeed, is it just to select any one name as the special representative of the present state of the science or the art of wound-treatment. The advances in our knowledge of the therapeutics of wounds, which it would be criminal on the part of a surgeon of to-day to ignore, are the results of the labors of many

men, in many different fields. In the present work, I have aimed to give credit in the proper connection, in the body of the work, to the various sources from which material has been drawn for its pages. In this place, however, an opportunity is afforded for me to acknowledge my indebtedness to my friend, Prof. Roswell Park, of Buffalo, for special assistance in the preparation of the chapter on Wounds of the Head, and to my colleagues, Drs. Geo. R. Fowler, Jas. E. Pilcher, and Glen. R. Butler, for many helps rendered in the course of my work.

LEWIS S. PILCHER.

4 Monroe Street, Brooklyn, N. Y.,
August, 1883.

This book is the property of
COOPER MEDICAL COLLEGE,
SAN FRANCISCO, CAL.
and is not to be removed from the Library Room by any person or under any pretext whatever.

CONTENTS.

PART I.

IN GENERAL.

SECTION I.

THE PRINCIPLES OF WOUND-TREATMENT.

CHAPTER I.

GENERAL CONSIDERATIONS ON WOUNDS.

PAGES

Importance of Wound-Treatment—Modern Methods of Surgical Study—Controversies on Wound-Treatment One Hundred Years Ago—John Bell—O'Halleran—Principles of Wound-Treatment Analyzed—Definitions—Classification—Influences that Modify the Healing of Wounds..... 3-20

CHAPTER II.

THE IMMEDIATE EFFECTS OF WOUNDS IN GENERAL—THE REPAIR OF WOUNDS—INFLAMMATION.

Constitutional Effects—Shock—Reaction—Traumatic Fever—*Local Effects*—Impairment of Function—Gaping—Pain—Hæmorrhage—Active Hyperæmia—*Union of Wounds*—Exudation—Vascularization—Connective-tissue Transformation—Cicatrization—Union by First Intention—Causes of Modified Repair—*Defects of Apposition—Defects of Protection—Defects of Nutrition—*

PAGES

Modified Normal Repair—Healing by Granulation—Healing by Secondary Adhesion—Healing by Scabbing—Suppuration—Disposition of Effused Blood and Dead Tissue—*Destructive Disturbances of Repair*—Inflammation—Infectious Wound-Diseases... 21–36

CHAPTER III.

THE RELATIONS OF MICRO-ORGANISMS TO WOUND-DISTURBANCES.

Results of Defects of Protection—Causes of Decomposition of Animal Tissues—Researches of Pasteur and Tyndall—Atmospheric Organisms—Resisting Power of Living Tissues—Species and Generation of Micro-organisms—Bacteria—Bacilli—Micrococci—Researches of Ogston, Koch and others—Views of Hunt—Summary—Wound-Suppuration—Septicæmia—Pyæmia—Micrococcus-poisoning—Clinical Demonstrations—Results of the Practice of Lister, Volkmann, and Nussbaum—Comparative Statistics of Amputations—Macewen's Osteotomies—Testimony of Sands, Stokes, Cheyne, and Little—Résumé 37–59

CHAPTER IV.

ASEPSIS AND ANTISEPSIS—WOUND-CLEANLINESS.

The Scientific Basis of Wound-Treatment—Ptomaïnes—Sepsis—*Asepsis*—*Antisepsis*—*Cleanliness*—Primary Cleansing of a Wound—Drainage—Cleanliness of Adjacent Tissues—Cleanliness of Wound-Dressings—Air-Purification—Antiseptic Sprays—Practice of Lister—Experiments of Stimson and Duncan—Effects of Sprays..... 60–68

CHAPTER V.

WOUND-DISINFECTION—ANTISEPTICS.

Antiseptics in General:—Comparative Germicidal Strength of Various Agents—Strengths Required to Restrain Germ-Development—Local Effect of Antiseptics on Tissues—General Toxic Effects. *Special Antiseptics*:—Corrosive Sublimate—Permanganate of Potassa—Carbolic Acid—Its Advantages—Its Disadvantages—Carbolic Intoxication—Chloride of Zinc—Salicylic Acid—Boracic Acid—Acetate and Aceto-Tartrate of Alumina—Iodine and Iodoform—Iodoform Intoxication—Naphthalin—Subnitrate of Bismuth..... 69–90

SECTION II.

THE PRACTICE OF WOUND-TREATMENT.

CHAPTER VI.

THE ARREST OF HÆMORRHAGE.

PAGES

Spontaneous Hæmostasis—Surgical Hæmostasis—Exposure to Air—Cold—Hot Water—Iodine—Alcohol—Turpentine—*Mechanical Pressure*—Compresses—Tampons—Acupressure—Forcipressure—Ligation—Catgut Ligatures—*Plugging Vessels*—Torsion—Coagulants—The Cautery—*Interrupting Blood-current*—Position—Forced Flexion—Digital Compression—Tourniquets—Elastic Bandage—Acupressure—Ligation—Cardiac Sedatives..... 93–127

CHAPTER VII.

THE GENERAL CONDITION OF THE PATIENT.

Shock—Anæmia—Auto-transfusion—Transfusion—Direct Transfusion—Defibrination of Blood—Technique of Transfusion—Dangers of Transfusion—Peritoneal Transfusion 128–137

CHAPTER VIII.

THE CLEANSING OF THE WOUND.

Hæmostasis—Sponging—Purification of Sponges—*Irrigation*—Continuous Submersion—Irrigating Fluids—*Drainage*—Natural Drainage—Artificial Drainage—Drainage-Tubes—Absorbable Tubes of Neuber, of Macewen—Capillary Drainage—Catgut Drains—Horse-hair Drains—Spun-glass Drains—*General Considerations as to Artificial Drains—Résumé*—Primary Drainage—Secondary Drainage—*Accessory Means of Wound-cleanliness*—Adjacent Skin—The Surgeon and his Assistants—Instruments and Appliances—Compresses and Protective Appliances—Purification of the Air—Spray Producers—*Cleansing Septic Wounds*—Curettes—Disinfecting Lotions..... 138–159

CHAPTER IX.

APPOSITION OF THE WOUND-SURFACES.

Position—Bandaging—Rollers—Compresses—Adhesive Plaster—Icthyocolla Plaster—Gold-beater's Skin—Collodion—Application of Adhesive Bandage—Ob-

PAGES

jections to Adhesive Bandages—*Suturing*—Needles—Needle-holders—*Thread*—Silk—Catgut—Silk-worm-gut—Horse-hair—Metal Wire—*Application of the Suture*—Stitches of Coaptation, of Approximation, of Relaxation—Knotting—Removing the Stitches—*Classification of Sutures*—Interrupted—Continuous—Pin—Quill—Bead—Button—Résumé..... 160–183

CHAPTER X.

PROTECTION AGAINST DISTURBANCES OF HEALING—ANTISEPTIC DRESSINGS.

Cotton Wool—Borated—Salicylated—Carbolated—Sublimate—Iodoformized—Bismuth—*Gauze*—Carbolated—Iodoformized—Naphthalinated—*Lint*—*Tow*—Oakum—Naphthalinated Oakum—*Jute*—*Turf-Mould*—*Charcoal*—Aluminated Charcoal—*Sand*—Sublimated Sand—*Coal Ashes*—*Sawdust*—*Wood-Wool*—*The Protective*—*The External Impermeable Envelope*—*Bandages*—*The Method of Lister*—*The Iodoform Dressing of Billroth*—*Esmarch's Turf-Mould Dressing*..... 184–204

CHAPTER XI.

PROTECTION AGAINST DISTURBANCES OF HEALING—(CONTINUED).

REST.

Position—*Compression*—*Immobilization*—Wire-gauze Splints—Plaster-of-Paris Splints—Shells—Encircling Plaster-bandage—Fenestrated—Interrupted—Combined—Change of Dressings—Anodynes..... 205–217

CHAPTER XII.

THE RELIEF OF DISTURBANCES OF HEALING—INFLAMMATION—GANGRENE—ERYSIPELAS—SEPTICÆMIA.

Treatment of Inflammation—*Opening the Wound*—*Incisions*—*Removal of Foreign Bodies*—*Position*—*Compression*—*Reduction of Heat*—Cold Compresses—Evaporating Lotions—Irrigation—Immersion—Ice-bags—Cold Water Coils—*Relaxation of Vessels*—*Abstraction of Blood*—*Interrupting the Blood-supply*—*Résumé*—*Treatment of Gangrene*—Incisions—Continuous Antiseptic Irrigation—Stimulants—*Treatment of Erysipelas*—Antiseptics—Subcutaneous Injections of Carbolic Acid—Superficial Applications—Naphthalin—Tonics and Stimulants—Antiphlogistics—*Treatment of Septicæmia*—Local Disinfection—General Treatment..... 218–233

PART II.

SPECIAL WOUNDS.

SECTION I.

VARIETIES THAT MAY OCCUR IN ANY PART OF THE BODY.

CHAPTER XIII.

SUBCUTANEOUS WOUNDS—INCISED WOUNDS—CONTUSED WOUNDS—LACERATED WOUNDS.

PAGES

Subcutaneous Hæmorrhage—Restriction and Absorption of Effusions—Massage—Dry Cupping—Sorbefacients—Inflammation—*Incised Wounds*—Rest—*Contused and Lacerated Wounds*—Peculiarities—Secondary Hæmorrhage—Primary Cleansing—Drainage—Necrosis of Tissue—Coaptation—Period of Granulation—*Contused Punctured Wounds*—Incisions 237–246

CHAPTER XIV.

GUNSHOT WOUNDS.

Peculiarities of Gunshot Wounds — Hæmorrhage — Wound-cleanliness — Immediate Antiseptic Occlusion—No Immediate Exploration—Classification—Statistics of Reyher—Non-occlusive Treatment—Enlargement, Cleansing, and Disinfection—Probes and Probing—Removal of Bullets—Immobilization. 247–254

CHAPTER XV.

EXTERNAL WOUNDS COMMUNICATING WITH FRACTURES OF BONES AND WITH JOINT-CAVITIES.

Peculiarities—Value of Antiseptic Methods of Treatment—MacCormac—Classification—*Recent Injuries with Slight External Wound*—Primary Antiseptic Occlusion—*Recent Injuries with External Wound of Considerable Extent*—

PAGES

Primary Exploration and Cleansing—Counter-incisions—Splinters of Bone—Drainage—Suture—*Wounds of Joints*—Incisions—Partial Resections—Protective Dressings—Immobilization—After-treatment—*Injuries not Recent and Septic*—Favorable Cases—Cases with Pronounced Septic Infection—Disinfection—Immobilization—Fenestrated and Interrupted Plastic Splints—Honeycomb Plaster Splint..... 255–266

SECTION II.

WOUNDS OF TISSUES COMMON TO ALL PARTS OF THE BODY.

CHAPTER XVI.

WOUNDS OF MUSCLES—TENDONS—NERVES.

Wounds of Muscles—Difficulties of Coaptation—Position—Bandaging—Suturing—Rest—Protection from Sepsis—Subcutaneous Ruptures—*Wounds of Tendons*—Healing of Subcutaneous Wounds—Difficulties of Open Wounds—Importance of Antisepsis, Protection, and Rest—Suturing Tendons—Lange's Case—Pauly's Case—*Wounds of Nerves*—Importance of Approximation of Divided Ends—Methods of Approximation—Suturing Nerves—Tillman's Statistics—Results reported by Page—Pye's Case—Page's Case—*Application of the Nerve-suture*—Direct Nerve-suture—Peri-neural Suture—The Suture Material—Conditions Requiring Nerve-suture—Neuroplasty—Tubular Suture—Contra-indications—Requisites to Success..... 269–279

CHAPTER XVII.

WOUNDS OF BLOOD-VESSELS.

Importance of Wounds of Blood vessels—Results to be Secured in Treatment—Difficulties—Obliteration of Vessels—Relations of Coagulum to Repair—Physiology of Repair—Apposition of Inner Serous Surfaces—Means of Compression—The Ligature—Ligation—Gross on Immoderate Violence in Tying a Ligature—Rules of Procedure—*Complications of Wounds of Blood-vessels*—Primary Hæmorrhage—Intermediary Hæmorrhage—Secondary Hæmorrhage—Diffuse Traumatic Aneurism—*Wounds of Veins*—Peculiarities—Phlebitis and Periphlebitis—Thrombosis—Effects of Septic Ligatures—Acupressure and Forcipressure—J. E. Pilcher's Case—Advantages of Aseptic Ligatures—Repair of Vein Wounds—Gross' Case—Langenbeck's Case—Lateral Ligation—Braun's Statistics—Necessary Precautions—Lateral Suture..... 280–298

This book is the property of
COOPER MEDICAL COLLEGE,
SAN FRANCISCO, CAL.
This book is not to be removed from the Library Room by any person or under any pretext whatever.

SECTION III.

WOUNDS OF SPECIAL REGIONS.

CHAPTER XVIII.

WOUNDS OF THE HEAD.

PAGES

Anatomical Considerations—Superficial Wounds of Scalp—Bruises and Contusions—Punctured and Incised Wounds—Extensive Lacerations—Superficial Gunshot Wounds—*Deep Wounds of Scalp with Injuries to the Cranium*—Signs of Compression of Brain Absent—Fractures of the Skull—Indications for Trephining—Fractures of the Base of the Skull—*Compression of the Brain*—Wounds of Intra-cranial Vessels and Sinuses—Injuries to Cranial Nerves—Wounds of Brain Substance—Hernia Cerebri—Wounds during Birth—Bandaging the Head—*Trephining*—Indications for the Operation—Operative Technique—Excision of Irregular Fragments—*Wounds of Eye*—*Wounds of Internal Ear*—*Wounds of the Face*—*Wounds of the Mouth*..... 301–332

CHAPTER XIX.

WOUNDS OF THE NECK AND OF THE THORAX.

Wounds of the Larynx or Trachea—Punctures—Longitudinal Wounds—Transverse Wounds—Suturing the Trachea—Antisepsis—Tracheal Canula—Intra-tracheal Polypi—Hæmorrhage into Trachea—*Wounds of Pharynx or Œsophagus*—Swallowing Interdicted—Œsophageal Tube—Primary Importance of Deep Union—Longitudinal Wounds—Gunshot Wounds—Transverse Wounds—*Wounds of the Great Vessels of the Neck*—Arteries—Vertebral Arteries—Internal Jugular Vein—Lateral Ligature—Cases of Parkes, Allis, Gerster, Lange, Lidell, and J. E. Pilcher—*Non-penetrating Wounds of the Thorax*—Wounds of Internal Mammary and Intercostal Arteries—*Penetrating Wounds of the Thorax*—Heart and Pericardium—Lungs—Pleuræ—Hæmothorax—Pneumothorax—Emphysema—Empyema and Hydrothorax—Résumé.... 333–350

CHAPTER XX.

WOUNDS OF THE ABDOMEN—OF THE PELVIS.

Non-penetrating Wounds of Parietes—Arrest of Hæmorrhage—Apposition—*Penetrating Wounds without Injury to Viscera*—The Peritoneal Wound—Protrusion of Viscera—Intestine—Omentum—Other Viscera—*Penetrating*

PAGES

Wounds with Injury to Viscera—Exploration of Abdomen—Diagnosis Positive—Diagnosis Presumptive—Arrest of Intra-peritoneal Hæmorrhage—Suture of Visceral Wounds—Lembert's Suture—Jobert's—Emmert's—Gély's—Gussenbauer's—Czerny's—The Continuous Intestinal Suture—Circular Invagination Suture—*Primary Cleansing of Peritoneal Cavity—Drainage—Peritonitis and Septicæmia—Wounds of the Bladder*—External Incisions—Laparotomy—Suture of Bladder—Catheterization—*Wounds of Anus and Rectum*..... 351–374

CHAPTER XXI.

WOUNDS OF THE EXTREMITIES—AMPUTATION.

Limitations of Conservation—Classification of Wounds possibly demanding Amputation—Duty in Doubtful Cases—*Period for Amputation*—Primary, Intermediary, and Secondary Periods defined—Effect of Antiseptics to prolong Primary Period—Shock a Contra-indication—Amputation to be done during Primary Period—*Point of Amputation—Treatment of the Amputation Wound*..... 375–378

INDEX 379–391

PART I.

IN GENERAL.

SECTION I.

THE PRINCIPLES OF WOUND-TREATMENT.

THE

TREATMENT OF WOUNDS.

CHAPTER I.

GENERAL CONSIDERATIONS ON WOUNDS.

Importance of Wound-Treatment—Modern Methods of Surgical Study—Controversies on Wound-Treatment One Hundred Years Ago—John Bell—O'Hallerans—Principles of Wound-Treatment Analyzed—Definitions—Classification—Influences that Modify the Healing of Wounds.

"The treatment of wounds is undoubtedly not merely the first stone, but also the corner-stone of surgery. By it surgery has attained its greatest triumphs; by it our branch of the profession has conferred its greatest benefits on mankind; by it each individual surgeon may hope to do more good than in any other way. Nevertheless it has ever been one of the opprobria of surgery; though it was the first work in which surgeons were engaged, it is at the present day one of the chief questions of surgery, and I trust it will remain so till it has attained to perfection."

These words by Professor George M. Humphrey, in the Surgical Section of the International Medical Congress of London, in 1881, do not too strongly set forth the importance of the subject of the treatment of wounds. It has been too much considered the highest exercise of the skill of the surgeon to make wounds, and the deftness and neatness, perhaps the brilliancy, with which the mere mechanical portions of the surgeon's work may be done have been considered as more important evidence of merit than the less striking and more prolonged duties required in the after-treatment, in the course of which his judgment and the resources of his science are continually being put to their highest test. Not only is this due in great measure to the fact that the awe and admiration with which

the laity look upon the deliberate wounds which are made by a surgeon, clothe such procedures with undue importance ; but it is also fostered by the improper methods of surgical instruction, so generally pursued, in which the chief interest is made to centre upon the operative procedures, and little or no attention is directed to the details of dressing and after-treatment.

It may be considered as one of the best evidences of the solid character of the advancement which is claimed for the surgery of to-day, that in its discussions and in its practice the principles of wound-treatment have attained an overshadowing importance, while the mechanical details of operative surgery have been relegated to a minor place.

That which has contributed to this end most especially is the application to surgery of the rigid experimental methods of investigation of modern Science, by which general impressions, formed from imperfectly noted or understood experience, have been substituted by exact demonstrations, guarded by adequate checks and careful precautions, that serve also to emphasize the limitations and variations in the applications of the principles which they demonstrate.

While surgery has thus always been a noble art, it may therefore now begin to claim, for the first time with some justice, that it is a noble science.

John Bell, in his delightful discourses on the "Nature and Cure of Wounds" (Edinburgh, 1795), claims that the surgeon "does all his services by observing and managing the properties of the living body ; where the living principle is so strong and active in every part that by that energy alone it regenerates the lost substances, or reunites in a more immediate way the more simple wounds." The picture which Bell proceeds to give of the opinions and discussions among the surgeons of his day, which is barely one hundred years ago, as to the treatment of wounds, is almost a burlesque upon what is taking place at the present day, with a change only in the particular points of discussion.

"Thirty years ago," he says, "surgeons had no settled notions that cut surfaces might be made to adhere ; they had no motive for saving the skin ; or where they had saved it, they did not know how it should be used, nor how much it might contribute to a speedy cure ; if they extirpated a tumor, they cut away along with it all the surrounding skin ; if they performed the trepan, they performed in a most regular manner that preliminary operation which they chose to call scalping ; or in plain

terms, they cut away six or eight inches of that skin which should have saved the fractured skull from exfoliation, and should have immediately covered and defended the brain; in performing amputation, they cut by one stroke down to the bone; and even when they performed the flap amputation they dressed their stump and flap as distinct sores.

"An exfoliation of the bone in these older operations was a thing unavoidable; so that it was part of their art and skill to procure exfoliation. And the filling up and final healing of their conical stump was so slow a process, so imperfect, and so many exfoliations of the bone, with other lets and hindrances, intervened, that it is no wonder their imagination was so much occupied about the digesting, incarning, and cicatrizing of wounds. Whenever a bone was laid bare, they believed that it must exfoliate before it could heal; until they saw this exfoliation perfect, till the bone had at least thrown off an outer scale, they would not permit it to heal; they would not lay the skin down upon a wound upon the shinbone, or if there was a lacerated scalp, they cut the torn piece off; a large part of the scalp could not be regenerated in less than several weeks or months; and so they made good their opinion by their practice; for very generally, in that space of time, the whole, or a part at least, of the exposed bone, was thoroughly spoiled. These were a few of the many mistakes committed daily by the older surgeons, who were contented with their theories about incarning and cicatrizing of wounds, too proud of their own art and too little inclined to follow the simple ways of nature."

The subject upon which discussion ran high in Bell's time was that of procuring the repair of wounds by immediate adhesion. The French surgeons had declared, not only that their flap amputation procured an easy and perfect cure, but they affirmed that often in three days the flesh of such a stump had adhered. To this a contemporary of Bell, O'Halleran, whom Bell characterizes as an excellent and most judicious surgeon, whose doctrine and practice was followed by all the best surgeons of that day, had replied: "I would ask the most ignorant tyro in our profession whether he ever saw, or heard even, of a wound, though no more than one inch long, united in so short a time;" adding, "these tales are told with more confidence than veracity; healing by inosculation, by the first intention, by immediate coalescence without suppuration is merely chimerical and opposite to the rules of nature."

The field of controversy has shifted since that day, but human nature has remained the same, and the same disinclination to accept doctrines

which do not agree with preconceived notions, or that seem to be opposed to particular experience, characterize the discussions of the present day. Many of the differences that have ever existed, or do still exist, have arisen, however, from the tendency to make theoretical considerations or individual experience, the elements of which have not been accurately analyzed and considered, the basis of generalizations that are esteemed comprehensive. It is not surprising that a catholic and philosophical student of the subject of wound treatment, as he reflects upon the changing views and methods of the past, as he observes the improving results attained by differing methods to-day ; and as he remembers the changes in his own views and practice at various stages of his experience, should hesitate to consider that the last step attained has accomplished that perfection which is the ideal to be striven for. Nevertheless no one will deny that there do exist ultimate facts, as to the methods by which the repair of injury is accomplished by living tissues and as to the nature of those influences, which may favor or hinder these reparative processes, and that these facts, when fully understood, will afford a sure basis upon which to build a perfect system of wound treatment.

Nor will it be asserted, in the light of the experience of to-day, that it is too much to expect that scientific research may accomplish the satisfactory and distinct resolution of the problems involved in the search for these facts, and establish them clearly and indisputably. Just in measure as this clear and indisputable establishment of these fundamental facts is being accomplished, does the treatment of wounds become emancipated from theory and prejudice, and becomes established upon a final and perfect basis. The varying conditions that attend wounds, conditions of constitution, of environment, of structure wounded, of agent and manner of wound, the presence or absence of needed material for treatment, and the measure of perfection in the care which may possibly be given to the wound will ever be the unknown and variable quantities that will test the judgment and skill of the surgeon in the application of principles to practice.

The *principles of wound treatment*, then, are of the highest importance as preliminary to the adoption of rational methods of practice, and by their study only can any steady and permanent advance in wound therapeutics be made.

In recognition of this, in the discussion of the treatment of wounds to which the present work is devoted, there will first be considered the

principles upon which treatment should be founded, and from this it will be possible to proceed to the application of these principles in the choice of methods to be adopted in practice. The plan of such a study will include :

First.—The immediate effects of a wound upon living tissues.

Second.—The processes instituted by nature, when undisturbed, for the repair of the injury.

Third.—Possible sources of disturbance, and their effects upon the natural reparative processes.

Fourth.—The means by which the natural reparative processes may be most effectually favored and the action of disturbing agents may be minified.

Before proceeding with this study, certain further general considerations should be noticed. These include matters of definition, of classification, and of the modifying influences of a general character that affect the repair of wounds.

Definitions.—A wound is a division of continuity of the bodily texture, produced, either directly or indirectly, by sudden mechanical force. Wiseman, "the Father of English surgery," limits the use of the term wound to injuries involving division of the skin. In his "Chirurgicall Treatises" (1676), p. 331, he thus discourses : "A wound is a Solution of continuity in any Part of the body suddenly made, by anything that cuts or tears, with a division of the Skin. This *Definition* differs much from what is usually delivered by Authors ; and it is fit it should. For they generally defining a Wound by a Solution *in parte molli*, do thereby exclude a Cut made into a Bone, as that into the *Cranium* by a Pole-axe, etc., which why it should not be called a Wound I know not. I say, it is *made by anything that cuts or tears.* Other Authors define it to be made by an external Instrument, etc. How then do they call that *fracturam cum vulnere*, a Fracture with a Wound, where the Bone from within makes the Wound, and thrusts itself quite through the Flesh. *Sennertus* adds to his definition, that it is to be done *à re secante* and *acuta :* yet he reckons those for Wounds that are made by Bullets, although it be a Cannon-shot. I do therefore think it fit to make my Definition more comprehensive, and to take in whatsoever makes a sudden Solution of continuity, at least immediately and by itself, on what Part soever it lighteth. So a Cut into a Bone is a Wound. Tearing the Flesh, Nerve, Sinew, Tendon, or Cartilage, by Bullet, Stone, Splinter, etc., is a Wound. Only I

add this restriction, that *the Skin must be* likewise *divided:* by which last words I exclude Fractures that come not through the Skin, and Contusions if the exterior parts be continuous. But by the word *Skin* I understand not only the external *Cutis,* but also the inward membranes of the Gullet, Ventricle, Guts, Bladder, *Urethra,* and Womb ; all which are capable of Wounds from Sharp Instruments, either swallowed or thrust into them."

Though the practical importance of the separate classification as made by this delightful old author, of injuries involving division of the skin or mucous membrane is still recognized, yet to make this an important element in a general definition is arbitrary and artificial.

The occurrence of a solution of continuity in any of the solid tissues of the body may be due to slowly acting causes, as the gradual waste of atrophy or the more active disintegration of ulceration, but a breach of tissue thus affected would not be a wound. There is involved in the idea the action of a force outside of the tissue itself, which by mechanical force has rent or divided its substance. Even in those cases in which so-called spontaneous rupture of muscular tissue occurs, it is not the contraction of the tissues alone that is the cause of the rupture, but the force opposed to it exerted through the bony levers into which it is inserted.

The term wound, therefore, is susceptible of a very wide range of application. Contusions, sprains, fractures, subcutaneous as well as cutaneous breaches of tissue are included in the term. In all essential particulars they will be found to be identical accidents, involving the same methods of repair and subject to the same principles of treatment, their apparent differences depending upon accidental differences of function, nutrition, relation to other parts, extent of traumatism suffered, and of exposure to disturbing influences from without.

These accidental differences are especially marked in the conditions which those wounds of bones that constitute fractures present. Though the method of repair, and the principles involved in treatment are the same in these wounds as in those of the soft parts, yet the application of these principles in the varied fractures of the bones of the skeleton involves so much of detail that, by common consent, these wounds have been classified apart. In accordance with this general usage, which is of practical importance, the consideration of fractures will be excluded from the plan of the present treatise.

Classification.—The first great division of wounds is into *subcutaneous* and *open* wounds, the division depending upon their relation to the

common covering of the body. Subcutaneous wounds include all which are unaccompanied by breach of the skin. Protected by the unbroken skin from external irritation and infection, their repair is usually rapid and undisturbed by untoward complications.

Open wounds, as a class, include all which exhibit a breach of the skin, or mucous membrane. They may present the widest extremes of tissue-breach, and of loss of substance. Those of this class, whose exposed surfaces may be quickly brought and kept in apposition, differ but little in their gravity from subcutaneous wounds. Failure to secure such apposition, whether by intention or from necessity, so modifies the course and duration of the process of healing, and so exposes the wound to dangers of disturbance from without, that such wounds constitute a well-marked class by themselves. To characterize this class only, the term open wound is most commonly employed.

Wounds are again divided, from the character of the agent or force by which they are produced, into *incised*, *punctured*, *contused*, *lacerated*, *gunshot*, and *poisoned* wounds, according as the wounding agent has been a sharp cutting edge, a penetrating point, a dull and bruising body, a tearing force, a projectile impelled by the force of exploding gunpowder, or one which carries with it into the wound a poison. These divisions, with the exception of the last, are indefinite general ones for convenience of description. They are all alike in kind, and differ only in the degree of the injury sustained. Whatever force or agent produces a breach of tissue, occasions likewise death of tissue in the track of the breach. The sharpest and most delicate cutting edge, when viewed through a lens of sufficient magnifying power, is seen to be rough and saw-like. Though the extent of the destructive action of an instrument is lessened according to the fineness of the edge, yet the track of the keenest edge through a tissue is lined by disorganized particles that have been killed by its impact. Between a slight and clean incised wound, in which the destruction of tissue is limited to the molecules traversed by the cutting instrument, and an extensive lacerated wound with roughly torn and contused edges, or between a slight bruise and a contusion producing the death and disorganization of large masses of tissue, the difference is one of degree, and not of kind. In the slight as well as in the severe injury there is dead tissue that must be taken care of.

The important practical difference which has always been recognized in the healing of incised and punctured wounds, as compared with con-

tused and lacerated wounds, has given importance to these distinctions as a basis for a clinical classification. These differences, however, depend simply upon the difference in the facility with which the devitalized tissue is prevented from becoming a source of disturbance to the healing of the wound in the several instances.

The class of *poisoned wounds* embraces a much wider range of injuries than its traditional application was intended to comprehend, and the most important practical classification of wounds is based upon the presence or absence of poisonous substances from a wound. Any substance is a poison which, in addition to the immediate gross chemical or mechanical effects which it may produce, displays a specific subtle quality by which the vitality of the tissues with which it comes in contact is degraded, a quality which is shown by the production of disturbances of the vital processes of an intensity out of all proportion to the immediate injury that may have been inflicted.

Decomposing animal matter, certain secretions of particular animals, conveyed by their bites or stings, and certain vegetable juices, when introduced into wounds, are followed by disturbances in their repair so marked that their separate classification as poisoned wounds has been natural. The uncomplicated effects produced by any traumatism have been long studied in subcutaneous injuries, in the repair of which, even when involving much contusion and laceration of soft parts and extensive effusion of blood, as a rule, sloughing, suppuration, and inflammation do not take place, but the effused liquids and the devitalized tissues are removed by absorption in due time, and no disturbance beyond that inflicted by the original wounding agent is experienced. Similar wounds, to which access of ordinary atmospheric air is permitted by reason of a breach in the skin, invariably have their repair disturbed by putrefaction and sloughing of the devitalized tissues, by decomposition and liquefaction of the blood-clots, by inflammation of the wound margins, and by a prolonged process of suppuration and granulation in the healing of the wound. Such results, however, do not take place when the air which is allowed access to a wound is purified of organic particles which are capable of inducing putrefaction in animal matter. Such wounds, though open and containing contused and devitalized tissues and blood-clots, pursue the same course of repair as do subcutaneous wounds. Whenever, therefore, inflammatory, suppurative, and sloughing conditions arise in an exposed wound it is the result of the introduction into it of foreign matters, which act as poisons in the dis-

turbances of the reparative processes that they create. The term poisoned wounds is thus made to extend in its application to the great mass of open wounds, those to which it was originally applied being simply examples of inoculation with special poisons. Upon this fact of the presence or absence in a wound of poisonous foreign material a classification of the greatest practical importance is possible, viz., into *aseptic* and *septic* wounds.

Aseptic wounds include all which are preserved from contamination by poisonous materials, whether such poison be applied directly to it, or be generated in it by the action of germs that gain access to it and find within it the conditions favorable for their growth. An aseptic condition in a wound may be obtained either by the protection which the wound receives from the first against the access of any septic agent, or by the power of living tissues to resist and destroy septic agents, or by the application to the wound of substances which destroy them. Examples of the first class are presented in subcutaneous wounds, and in operative wounds which are inflicted with certain precautions; examples of the second class are seen in all open wounds in which union by first intention is secured, notwithstanding at the time of their infliction they were freely exposed to ordinary air; examples of the third class are presented by wounds in which the application of antiseptic substances has been successful in arresting the action of whatever septic agents may have previously gained access to them. Asepsis in a wound is of the highest practical importance. As long as it is maintained, no decomposition of the secretions of the wound takes place, no sloughing of killed or partly killed tissue occurs. When the proper cares to favor the nutrition of the wounded tissues are rendered, the healing of the wound progresses without pain, inflammation, or suppuration, and the least possible amount of cicatricial tissue is produced. To secure an aseptic condition in a wound, or to approach it as nearly as possible, is the first and most important indication in wound-treatment.

Septic wounds include all in which any agent capable of exciting fermentation or putrefaction lodges and grows. They may present the most widely different degrees of wound-disturbances dependent upon the varying conditions which the special wound may present, and upon the character of the treatment which is instituted, but in all cases they are attended with some degree of inflammation and suppuration, and with sloughing of dead tissue. The septic agent may be introduced by the body that inflicts the wound, or by the dressings that are applied, or may

be among the dust particles that float in the air to which it is exposed. In very rare instances, also, it is possible that it may be conveyed to the wound through the blood of the wounded person himself.

Modifying Influences.—The effects in individual cases which particular injuries produce are never the same, and may widely differ. They are modified by *idiosyncrasy, mental state, age, previous constitutional condition, disease,* and *hygienic conditions.*

Differences as to the ability to bear injuries exist among races, nations, families, and individuals. The Latin races have less resisting power than the German and Anglo-Saxon. Oriental nations surpass the Occidental in their tolerance of injuries. Of individuals of apparently equally good physique, and enjoying the same hygienic surroundings and treatment, one will recover from the most serious injury speedily and without serious complication, while in the other an injury, apparently much less severe, may end fatally or in prolonged illness.

The power of resisting the effects of extraneous influences to some degree is a characteristic of all living matter. Its cessation is death, and a dead tissue and a passive tissue are synonymous. The quality of the vital resisting power inherent in the constitution of an individual cannot be estimated by any known signs. It may be modified by other conditions, but in some degree it is always present as a powerful unknown factor influencing the result of any case. It is a measure of the vital force of the particular individual, and is what is meant by the term idiosyncrasy as here used.

Mental states may modify greatly the effects of injuries. The shock which attends the reception of an injury is particularly closely associated with mental conditions. The mere apprehension of injury has been known to produce death through shock, and the ability to rally from the physical impression made by an injury is modified by the state of mind of the injured person. The reparative processes likewise are subject to the influence of mental conditions. They are promoted by the emotions of hope, joy, expectation, confidence, and resignation, and may be hindered by fear, anxiety, disappointment, and allied states. This is illustrated on a large scale by the difference which has been remarked in the repair of wounds which have been sustained by a victorious army and those by a defeated and dispirited one.[1] In general, it is important to

[1] "The influence of the mental condition on the results of wounds is undeniable. All reports agree that the wounded of victorious troops, elated by the successes

remember that, as it is expressed by Tuke,[1] "The influence of the mind upon the body is no transient power; in health it may exalt the sensory functions or suspend them altogether; excite the nervous system so as to cause the various forms of convulsive action of the voluntary muscles, or depress it so as to render them powerless; may stimulate or paralyze the muscles of organic life, and the processes of nutrition and secretion—causing even death; that in disease it may restore the functions which it takes away in health, reinnervating the sensory and motor nerves, exciting healthy vascularity and nervous power, and assisting the *vis medicatrix naturæ* to throw off diseased action or absorb morbid deposits."

The influence of age in modifying the effects of wounds is exerted in a threefold way. At the two extremes of life the immediate shock from injuries is more liable to be serious, but in the young it is more quickly and completely rallied from, while in the old its development may be more slow in its manifestation and ultimately overwhelming in its effects. Secondly, the reparative power is greater in all parts of the young than in those of the older individuals of all species. The activity of nutrition in youth favors repair after injury; the effects of this favorable influence are notable in the difference between the readiness and completeness of repair in children and that in adults. Lastly, the freedom from pre-existing organic disease in early life prevents complications, which become more frequent as age advances. As the result of these various conditions, the general rule may be said to be that, after the age of thirty years, the ability to resist injury decreases steadily with the increase of years.

In connection with the influence of age upon the results of wounds, it may be well to recall the experience of Paget, as given in a clinical lecture on "The Various Risks of Operations."[2] He says: "We have a large

---

achieved by their own bravery and that of their comrades, did better than those of defeated armies. The most striking example of this influence of the mental condition in the successful treatment of wounds in modern times is the fearful mortality among the French, after shot wounds of all kinds, in the war of 1870–71. The excessive mortality of that campaign was undoubtedly largely owing to the mental depression caused by a succession of reverses rarely met with in the history of warfare" (Medical and Surgical History of the War of the Rebellion, Part Third, Surgical Volume, page 868).

[1] D. H. Tuke: Influence of the Mind on the Body.

[2] Clinical Lectures and Essays by Sir James Paget, Bart., edited by Howard Marsh, F.R.C.S. London, 1875.

number of printing offices in the neighborhood of the hospital; and every office employs many boys from twelve to sixteen years old; and hardly a week passes but we have one or more of these boys brought in crushed by the printing-machines. Fingers, hands, and arms are thus mutilated; and I know of no class of patients that recover more remarkably. Not only do they not die, but their wounds heal steadily and quickly; they escape erysipelas and spreading suppurations and secondary hæmorrhages; and often, when, to save any piece of a hand, we leave bits of skin that seem as if they could not live, they yet do live and grow good scars." Again, referring to those advanced in life, he continues: "All the risks of doing badly are at their maximum in some among the old; but these are some of the risks for which they will always need your especial care. The old are, much more than others, liable to die of shock, or of mere exhaustion within a few days after the operation. They bear badly large losses of blood, long exposure to cold, sudden lowering of temperature, loss of food. Large wounds heal in them lazily; and hence a prolonged liability to secondary hæmorrhage and other mischiefs of open wounds. Their convalescence is often prolonged; and you may expect to meet sometimes with great disappointment in having your old patients die with some slight casual disease, as if exhausted by the long expense of vital power in healing large wounds. They get all but well: and then, after seeming for some time stationary, they fade and waste and die."

Under the head of "Constitutional Conditions," are to be classed certain general states of the blood, or of the nerves, or of the general nutrition, in which, while there is not a recognizable disease, there is still a departure from a perfect standard of health. It is rare, if ever, that any individual would satisfy the strict requirements of a perfect standard, and the varying degree and combinations of departures from this standard, which different individuals present, mark the constitutional differences of individuals. It differs from what I have termed idiosyncrasy, in that it is a measure of the extent to which vitality has been sapped in the tissues of an individual, while the former refers to the vigor with which the tissues are able to resist deteriorating influences. Plethora, anæmia, obesity, these are gross examples of constitutional differences. I am inclined to class here also the peculiar vulnerability of tissue which constitutes the scrofulous diathesis. The conditions which result from addiction to alcoholic stimulants and to gluttony; from the exhaustion of

overwork, underfeeding, or mental strain ; from vicious habits, and from habitual inhalation of vitiated air ; these are some of the more marked examples of influences, which, by their effect upon bodily nutrition in general, aggravate the effects of injuries by prolonging the period of their repair, and rendering them more easily affected by extraneous disturbing influences.

Closely allied to the conditions just remarked upon, are well-marked diseased states, such as syphilis, tuberculosis, malaria, diabetes mellitus, and scurvy, which, by the nutritive defects which they determine, delay repair, often arrest it, and subject wounds to the most serious complications. The pre-existence of pyæmia, septicæmia, erysipelas, phlebitis, or any diffuse inflammation, will add special dangers to any superadded traumatism. Diseases of the various organs of the body, and particularly cardiac, pulmonary, hepatic, and renal diseases, modify the effects of wounds both directly, by the constitutional states which they create that interfere with repair and diminish the resisting power of the tissues in general, and indirectly, by the reaction of the injury upon the pre-existing affection, producing in it temporary exacerbation, or permanent and progressive aggravation, with not infrequently speedy death.

By their relation to the functions of nutrition in general, hygienic conditions also exert an important modifying influence on the healing of wounds. Food, insufficient in quantity or bad in quality, extremes of temperature, absence of sunlight, depressing climatic conditions, lack of exercise, insufficient and impure air—these not only create previous constitutional conditions unfavorable to repair, but, when continued after the reception of a wound, directly diminish its activity. Erichsen,[1] in discussing diet after operations, remarks : "The soldier or the sailor on active service is often exposed to serious injuries that necessitate the more important operations at a time when his constitutional powers have already been broken down by scurvy, dysentery, or some other similar affection, resulting as much from the deficient quantity as from the unwholesome character of the food with which alone he can be supplied. And after the operation his only available nutriment may be of the coarsest character, possibly salted, and imperfectly cooked. In such circumstances operation-wounds do not heal, or they assume a peculiar gangrenous character ; or the patient sinks from ulceration of the intestinal

[1] Science and Art of Surgery, vol. i., p. 31. Philadelphia, 1878.

mucous membrane. The mortality of operations becomes enormously increased; and there can be little doubt that thousands of deaths which have occurred in wars between the most civilized nations and the best appointed armies may be attributed to these causes." The important influence which diet may exert upon repair should not be overlooked in the treatment of wounds. An ample supply of food, in a digestible form, with care observed that the digestive powers of the patient should not be overtaxed, with due regard to the personal tastes and instincts of the patient, will form the general rule to be followed. The weather, in which are included temperature, humidity, atmospheric pressure and movement, may also depress or stimulate the general nutrition, and thus influence the repair of wounds. Moderately warm weather, if it be not sultry and oppressive, favors repair directly, and also indirectly, by encouraging the opening of doors and windows and thus permitting free air-supply. A dry, clear atmosphere is exhilarating; a damp, raw one, depressing. Dr. Addinell Hewson,[1] from a comparison of the meteorological records and the records of operations performed in the Pennsylvania Hospital during a period of thirty years, found that with an ascending barometer, the mortality of operations was a little less than eleven per cent., with a stationary barometer, more than twenty per cent., and with a descending barometer, more than twenty-eight per cent. The frequency and mortality of pyæmia bore a direct relation to low barometrical pressure and moisture of air, while the deaths from shock occurred in a constant ratio with the opposite condition, dryness of weather.

Wales, in his work on "Surgical Operations and Appliances" (p. 124), speaking of the observations of surgeons in hot climates, that wounds heal more quickly under an elevated temperature than the reverse, says: "This is strikingly illustrated in the influence of our high summer heats over the adhesive process, which takes place much more surely than in cold weather and damp cool latitudes. The same thing is observed in the constitution of the Arab, whose climate, active habits, and diet produce a spare and sinewy frame and a sort of dry temperament very favorable for the quick healing of wounds. I have made the same observation in some parts of the East Indies, where the population is under analogous influences. In the Gulf of Mexico the heat during the summer is excessive; and it was during a period of this sort of weather that I

[1] Pennsylvania Hospital Reports, 1869.

received into the hospital under my charge, at the mouth of the Mississippi River, a large number of the wounded during the naval operations against New Orleans. Though the buildings were crowded with the wounded and fever patients, all of the wounds healed with unusual rapidity; and of fifteen cases of amputation of the thigh and arm, but two died, both of them after secondary operations, one of the patients having lost a good deal of blood from having his knee shattered by a rifle-shot; in the other case, disarticulation was performed at the shoulder for a gunshot wound of both the axillary artery and vein." Rochard, in speaking of the healing of wounds in hot climates, says: "All of our confrères point out the rapidity of their course and the promptitude with which they heal. I have myself been able to verify it often in Madagascar. The bad guns of which the Sacolares made use, often burst in their hands, and I have seen some of these complicated wounds, for which I had proposed amputation, heal with a wonderful facility, in spite of the most irrational treatment. Intertropical climates are favorable to the efforts of conservative surgery; and operations, when it is impossible to avoid them, succeed better there than in Europe. The same observation has been made in Oceanica, on the coast of Africa, in South America, and in the Antilles. It explains the almost constant success of the amputations of naval surgeons in equatorial stations, and the remarkable cures that they often obtain when it is possible to abstain from them."

The stimulating effects of sunlight upon nutrition should also be regarded in the hygienic management of the wounded. Next to the necessity of fresh air supply, that of sunlight has assumed importance in the present prevailing views as to the arrangement of hospital wards. There is an instinctive craving for the light innate in all living beings, which becomes more marked whenever, for any reason, there is a depression of vital power. Both pathetic and truthful is the observation of Florence Nightingale, in her "Notes on Nursing," that "it is curious to observe how almost all patients lie with their faces turned to the light, exactly as plants make their way toward the light. A patient will complain that it gives him pain lying on that side. 'Then why *do* you lie on that side?' He does not know, but we do. It is because it is the side toward the window." The effects of sunlight upon nutrition and growth have an excellent illustration in the hygiene of the growing child. The special application of this illustration to the course of wounds in adults depends upon the fact that in the repair of all wounds there is a return of

the local tissues engaged in the repair to that condition which marks the tissues in general of the growing child.

Insufficient air is synonymous with impure air, for the purest air, if not renewed with sufficient frequency becomes speedily poisoned by the exhalations from the persons of those breathing it. This, which is true in health, is still more quickly accomplished when the bodily exhalations are rendered more offensive by disease. It becomes therefore more important for the well-doing of the sick than it is for the welfare of the well that an unlimited supply of pure air should be supplied. When to the natural sources of air-contamination there is added the emanations of suppurating wounds the need of constant change in the surrounding air is more emphatic still, if its purity is to be preserved. While much attention has been directed to the importance of the adequate ventilation of hospitals, in the wards of which numbers of wounds are assembled, it should not be forgotten that the same necessity exists for isolated cases in their own homes that they do not become sources of infection to themselves. Absolutely pure air is not attainable in the ordinary conditions of life. While it is the great oxygen-carrier for the needs of the living body, it receives in exchange from the body the débris of its disintegration. It is the vehicle of transportation of an infinite variety of floating matter, the great mass of which is organic in character. Putrescible organic matter cannot long be exposed to the air without becoming the recipient of putrefactive germs from it. Aseptic wounded surfaces quickly become septic when exposed to it by reason of the floating septic particles that it conveys. The best stimulant to the vital resisting power of a living tissue, by which the effects of sepsis is antagonized and overcome is perfectly oxygenized blood. The air thus carries both the bane and the antidote. The practical end therefore to be aimed at, in any given air-supply, is that there shall be as small a proportion of the bane and as large a proportion of the antidote as possible. This involves the removal, the suppression, or the diffusion, as much as possible, of all sources of contamination, and the dilution of that which is unavoidable by the introduction of the largest quantity practicable of the purest air attainable. The purity and the sufficiency of the air are thus seen to have a double relation to the healing of wounds, one a general relation, which the air shares with other hygienic conditions, and the other a special relation as a carrier of and an antidote to sepsis. This latter relation demands further notice. As the sources of infection are multiplied and brought near to wounds capable of becoming infected, will the action

of the air as a medium of infection be exemplified in its highest degree. This is accomplished by the accumulation of numbers of septic wounds in one building with limited ventilation capacity. Says Erichsen,[1] "The overcrowding of wounded people, whether the wounds be accidental or surgical, will inevitably produce one of the four septic diseases, phagedæna, septicæmia, pyæmia, or erysipelas. When the word '*overcrowding*' is used in connection with surgical hygiene, it does not mean the heaping together of the sick and wounded in one building beyond what it is intended to hold; but it means the accumulation in one ward or under one roof of a greater number of patients than is compatible with such purity of air as to render the septic poison incapable of development or of propagation in it."

The value of air as an antiseptic agent is shown by the diminished prevalence of septic diseases when those, who by reason of open wounds are favorable subjects for their development, are isolated from each other, and are supplied with abundance of comparatively pure air. Still the air, however great its quantity, does not destroy the particles of infection that it dilutes. It acts only by increasing the resisting power of the tissues and by lessening the amount of the infective material deposited at any one time. It is the presence of these infective particles that make it important that to a person suffering from an open wound an amount of air should be supplied in excess of that required for the ordinary purposes of healthy life. Whatever means then may diminish the number or activity of the agents of infection will by that much reduce the importance of an unusual air-supply in the treatment of wounds.

In concluding these paragraphs on the general modifying conditions that influence the course of wounds, I remark that their pertinency depends upon the truth that the treatment of a wound involves the treatment not only of the particular breach of continuity, but also of the wounded person as a whole. It is possible that in the special direction of attention to the details of local treatment, matters concerning the general state of the patient may be overlooked or slighted. Too often, perhaps, this is the case. The duty of the surgeon extends, however, beyond the restricted field of binding up the wound and keeping it free from irritation. His ministry to the mental state of the wounded may be of the utmost importance. The ability to excite in the minds of those subject to

[1] Science and Art of Surgery, vol. i, p. 33. Philadelphia, 1878.

his care a feeling akin to that of the beleaguered garrison of Metz toward Paré, who cried out upon his arrival among them, "We have no longer any fear of dying, even if we should be wounded; Paré, our friend, is among us," may make the difference between life and death. The special risks from age, from the previous constitutional condition. or diseases of the injured, must be appreciated and met, and the hygienic conditions in which the wounded man is placed must be made as good as possible, before the whole duty of a surgeon is accomplished.

CHAPTER II.

THE IMMEDIATE EFFECTS OF WOUNDS IN GENERAL—THE REPAIR OF WOUNDS—INFLAMMATION.

Constitutional Effects—Shock—Reaction—Traumatic Fever—*Local Effects*—Impairment of Function—Gaping—Pain—Hæmorrhage—Active Hyperæmia—*Union of Wounds*—Exudation—Vascularization—Connective-tissue Transformation—Cicatrization—Union by First Intention—Causes of Modified Repair—*Defects of Apposition—Defects of Protection—Defects of Nutrition—Modified Normal Repair*—Healing by Granulation—Healing by Secondary Adhesion—Healing by Scabbing—Suppuration—Disposition of Effused Blood and Dead Tissue—*Destructive Disturbances of Repair*—Inflammation—Infectious Wound-Diseases.

The immediate effects of a wound are twofold in character, *constitutional* and *local*.

Constitutional Effects.—All wounds, of every degree, produce at first a depressing effect upon the whole body. This is accomplished through the nervous system, may be so slight and transitory as to be unnoticed, or may be so profound as to cause instant death. This general depression constitutes *shock*. It manifests itself most prominently through the circulation by diminution in the contractile force of the heart and arteries—reflex vaso-motor paralysis. The varying degrees of depression of nerve-force and of heart-failure which may be produced by the infliction of a wound cause the symptoms of shock to vary from momentary pallor and mental confusion to a condition of profound prostration. When the vital powers rally from this state of depression and the different organs begin to resume their proper functions *reaction* is said to have taken place. In the most favorable cases reaction is gradual and progressive, though it may occupy many hours, or even days, in its course. Returning color to the face and increased power in the heart's action are its earliest signs. In certain cases fluctuations in the reaction occur, relapse alternating with improvement for a variable time. In some cases there is an imperfect reaction, characterized by rapid and weak heart's

action, cerebral excitement, muscular tremor, and high body temperature. The result of such a condition is doubtful, speedy death or ultimate recovery after a prolonged struggle being possible.

The reaction from shock is commonly attended with elevation of the body temperature, quickening of the pulse, thirst, derangement of the secretions, restlessness, and headache. This fever of reaction may be so trifling and evanescent as to escape notice ; its grade of severity depends chiefly upon the nervous excitability of the patient, his previous constitutional condition, and the amount of local irritation produced by the injury. Children manifest it most readily. It is of reflex nervous origin, makes its appearance usually within a few hours after the reception of an injury, and may be expected to decline on or after the second day. Its most severe manifestations are seen in cases of imperfect reaction, its combination with which produces the condition of excitement with prostration which characterizes these cases. It may be dangerously intense, and is then apt to be accompanied by a delirium, which is generally wild in character but temporary in duration, subsiding with the restoration of the general bodily functions. This reactive fever is to be distinguished from the fever which complicates the repair of injuries, which does not develop until two or three days after an injury, and is dependent upon general blood-infection by absorption of septic matters from the injured part. The two might very properly be designated as *primary* and *secondary traumatic fever*. The secondary is often engrafted upon the primary.

Local Effects.—All breaches of tissue are produced either by a force of traction, tearing asunder the elements from each other, or by direct pressure forcing the elements asunder. The first constitutes a *laceration*, the second a *contusion*. When a laceration is inflicted a greater amount of damage is likely to have been done than the particular breach would indicate, owing to the wide distribution of the effects of the strain, the culmination of which at the point of rupture alone is declared by the wound. The strains, rents, and ruptures of ligaments and capsules that result from joint-wrenches, distortions, or dislocations, muscular ruptures, the sprains of tendons and tendon-sheaths occasioned often in violent manual efforts, the tearing away of epiphyses and bony prominences through strain upon the muscles or ligaments attached to them, and rents in the substance of internal organs, or their separation from their connections by the jar of falls, are examples of subcutaneous lacerations. By the prolonged impairment of function which they produce they illustrate

the force of the statement as to the wide distribution of the effects of strain. A contusing force may likewise act as a lacerating force upon the tissues beyond the range of its direct impact, and the most severe wounds, as regards the difficulties which attend their treatment, are those in which laceration and contusion are combined, as in the accidents produced from the entanglement of limbs in machinery or by their crushing under the wheels of cars. In a pure contusion, however, that is a breach produced by direct pressure only, the traumatism is limited in its extent by the area of the impact, but the crushing of the tissues may be of any grade, from the imperceptible molecular divisions of a clean incision or a slight bruise to the pulpification of large masses of tissue.

The local effects of a wound, however produced, may be classified under the five divisions of, 1, *Impairment of Function;* 2, *Gaping;* 3, *Pain;* 4, *Hæmorrhage;* 5, *Active Hyperæmia.* Of these, the four first can receive here but the briefest mention. The last will exact more consideration, as it is the initial condition upon which is built up the consequent repair of the wound.

Impairment of function is the necessary and immediate result of tissue-breach. Its character is determined, in a particular wound, by the varying functions and relations of the tissues that have been severed. Its extent and duration will depend upon the amount of injury, the activity and regularity of the processes of repair, the perfection of repair of which the tissue is susceptible, and the amount of new material needed to fill up any gap between the divided tissues that may have resulted from loss of substance or gaping.

Gaping depends upon the contractility of the tissues and is due to the destruction, by the solution of continuity of the tissue, of the natural force by which they are kept extended. It becomes important when the wound is transverse to the direction of the principal fibres of an organ. Tissues in a state of tension, tissues in whose structure there is much elastic tissue, as the skin and arteries, and tissue that has the power of contracting, as muscular tissue, when wounded, exhibit gaping in the most marked degree.

Pain results from the impression made upon the sensory nerves of the part, and hence varies with the nerve-supply of the parts. The temperament, likewise, of the individual, modifies the amount of pain experienced. Mental preoccupation or excitement often prevents the perception of pain. Great rapidity in the infliction of a wound diminishes the pain resulting.

Extensive operations with the assistance of the "surgical engine," by which the instruments used are made to revolve with inconceivable rapidity, may be done with little or no pain. A temporary benumbing of the parts is produced when the injury is instantaneously inflicted. Subsequent sensation is one of smarting or burning. This is experienced in all wounds, and is of short duration.

The amount of hæmorrhage which is provoked by a wound depends upon the number, size, and character of the wounded vessels, and the conditions which either the situation of the wound itself or the art of the surgeon supplies to arrest it. The natural hæmostatic is the coagulation of the blood, which spontaneously seals up the divided extremities of the capillaries and smaller vessels, filling them as far as to the next branches of the vascular network. In open wounds the effused blood, in great part, either spontaneously flows away or may be wiped away; a slight layer of coagulated blood, however, remains, with rare exceptions, in the interstices of the wound surfaces. In subcutaneous wounds the character of the tissue in which the vessels lie influences also the extent of blood-effusion. Loose connective tissue favors extensive and rapid infiltration. The escape of blood into the cavities of the body may be a dangerous complication both by reason of the possible amount of the hæmorrhage, and from the pressure which it may exert upon important organs. Blood-clot may interfere with repair, either mechanically, by preventing apposition of the wound-surfaces and maintaining a gap to be slowly filled up by new tissue, or by affording a favorable substance for the lodgement and development of septic matter from without.

The parts immediately adjacent to a wound speedily swell somewhat, and by their increased redness show some capillary turgescence. From the dilated capillaries an amount of plasma is exuded in excess of the normal, which infiltrates the tissues adjacent to the wound and appears as a more or less copious effusion—wound-secretion—upon the free surface of the wound when accurate apposition is not maintained. The amount of this capillary dilatation and of the consequent effusion and swelling, can be greatly restricted by shielding the wound from further irritation, keeping the parts at perfect rest, and subjecting them to equable and gentle compression. A certain amount of capillary distention in the wound-flaps may be passive, the result of the closure of a part of the blood-paths, by which a less numerous series of channels are provided for the transmission of the same amount of blood, but the chief element in its produc-

tion has been demonstrated to be a quality inherent in the capillary vessels of dilating when irritated. The first and immediate effect of the irritation of any part is increased activity of the capillary circulation of the affected part. The capillaries dilate and the blood-pressure in them increases. This state is called *active hyperæmia*, or *afflux*, and occurs only as the result of irritation, and in wounds is the direct consequence of the local irritation produced by the traumatism that has at the same time produced the solution of continuity. In addition to this quality of dilatation displayed by the vessels themselves, it is probable that in most injuries there is present the added influence of the vaso-dilator nerves, affected indirectly through the sensory nerves of the implicated region, for it has been observed that excitation of a sensory nerve produces increased activity of the capillary circulation in the part in which the nerve originates. This active hyperæmia quickly subsides, without having produced any marked alteration in normal tissues, when the irritation ceases, if it has been temporary. But when the irritating force has at the same time produced a breach of tissue, the hyperæmia is prolonged and quickly provokes active tissue-changes. These changes consist of *exudation* and *cell-germination*. Through the conditions which these new processes introduce into the wound, agglutination and ultimate firm union of the divided tissues by a more or less highly organized bond is effected.

Union of Wounds.—The preceding description of the capillary conditions that produce and characterize the active hyperæmia that follows wounds has been based upon the observations of Stricker.[1] The succeeding statements as to the character of the histological changes that attend the process of repair are derived from the same authority. The immediate effects of a wound have been traced to the point where an exudation of liquid from the hyperæmic capillaries has taken place. This exudation consists of an increased effusion from the vessels of nutritive plasma, or coagulable lymph, with some of the white corpuscles of the blood. The exuded plasma is appropriated by the cellular elements of the tissues. Under its stimulus, these normal tissue-cells, which had become contracted and fixed, enlarge, absorb the basis substance in which they are embedded, multiply by segmentation, and again become amœboid and capable of development and organization into new tissue,

[1] Disturbances of Nutrition and Pathology of Inflammation. The International Encyclopædia of Surgery, vol. i. New York: William Wood & Co., 1882.

being identical in character with embryonic tissue, the characteristic of which is that it is composed of amœboid cells, separated by narrow traces of intermediate or basis substance, and that these cells or masses tend to multiply actively by segmentation, and by a power of differentiation inherent in themselves produce the development and growth of the different organs and tissues of the body. The older the tissue becomes, the greater proportion does the intermediate substance acquire, and the more slender are the cells and their processes. It is proper to say, therefore, that the divided tissues which are in process of reunion return, as a preliminary step, to the embryonic state. By the proliferation of the tissue-cells thus revivified new cells are developed, and the process of cell-formation continues until the breach is filled. The new material thus formed, consisting of cells embedded in a slight amount of gelatinous uniting substance, blends with the softened reverted tissue on either side, and forms a bond of union that within twenty-four hours is sufficiently formed to agglutinate the divided surfaces. There follow next, in due order, the vascularization and the connective-tissue transformation of this new tissue. Within a few hours new capillary loops extend into the cell-mass from the surfaces of the recently divided tissue. These inosculate freely with each other. With the restoration of the circulation through the new tissue, the active hyperæmia in the adjacent blood-vessels subsides, and a retrograde metamorphosis of the cell-mass begins. Some of the cells become entirely converted into basis, or connective substance, while others remain, but contracted and changed in form by a similar transformation of portions of their mass at their circumference, into basis substance. The basis substance speedily becomes quite stiff and fibrinous, and assumes a fixed character which is influenced by the adjacent tissue. The fixed character finally assumed by this basis substance determines the ultimate character of the new tissue. As a rule, the highest development which the new material formed can reach is that of connective tissue, but a perfect regeneration, as regards form and function in the case of nerve, muscle, and bone tissue may be attained. The capillary network formed in the new tissue is at first more abundant than that of the adjacent tissue, so that the cicatrix appears as a fine red stripe, but in the further history of the tissue a tendency to condensation and atrophy is manifested, by which a large proportion of the newly formed vessels become converted into solid, fine connective-tissue strings, and the whole cicatricial tissue contracts and pales, becoming more dense and

of a lighter color than the adjacent tissue. The repair of all breaches of tissue is accomplished by essentially the same process, subject only to minor differences arising from peculiarities of structure. This process consists—as has been now described—in a modification simply of the normal nutritive processes at the seat of injury, by which the tissues to be repaired return to their embryonic state, and new embryonic tissue is formed between them with which they blend. By the organization and development of the new tissue a permanent bond of union is formed. In no case is union of divided tissue effected without the interposition of new material. When divided tissues are at once brought into perfect apposition, and there retained and shielded from disturbance, the amount of new tissue required for the accomplishment of union will be extremely small, and may be with difficulty recognizable, but its existence in sufficient degree is nevertheless undeniable.

When rapid and uncomplicated union of divided surfaces takes place, union by *first intention*, or by *primary adhesion*, is said to have been accomplished. It is seen in its ideal perfection in the repair of many simple incised wounds, in which, even by the third day, the union may become so firm that extraneous means of retention are no longer necessary.

To secure this primary adhesion it is necessary that a close apposition of the divided surfaces be effected and preserved, that all sources of irritation be avoided, and that the conditions which favor nutrition in general be maintained. When any of these conditions fail to be secured, modifications in the typical process take place. The conditions that modify the processes of repair, and tend to prevent union by first intention may be classified as 1, *defects of apposition*; 2, *defects of protection*; 3, *defects of nutrition*. An analysis of the various conditions included in each of these classes is subjoined. Each is of importance in guiding the treatment to be adopted in any given case, and will repeatedly reappear for consideration in the succeeding pages of this work.

Defects of Apposition.—Close apposition of divided surfaces may be prevented by:

a. The natural gaping of the divided tissues in the absence of the necessary means of coaptation and retention.

b. The character of the injury itself, as in superficial excoriations and burns, and in wounds in which there has been an extensive loss of substance, or by which a large, flat surface has been exposed.

c. The accumulation between the divided surfaces of blood and of wound-secretions.

d. The presence of foreign matter between the wound surfaces.

Defects of Protection.—By failure to properly protect a wound the injured tissues may be exposed to continued or repeated irritations. The sources of such irritation may be found in:

a. Motion, by which the apposition of the divided surfaces is disturbed, rupture of the new adhesive material produced, and the conditions of the original injury renewed in tissues already weakened by that injury.

b. Direct mechanical violence, which includes not only rude handling, friction, and gross mechanical injuries of every kind, but also the less tangible injuries inflicted by minute foreign particles that may have been permitted to remain in a wound.

c. Chemical irritants, including the products of the decomposition of retained secretions, and of masses or particles of dead tissue.

d. Infection by poisonous agents, including the floating organic matter of the atmosphere.

Defects of Nutrition.—The causes of defective nutrition may be *general* and *local*. The general, or constitutional conditions which produce defective nutrition have already been considered (see page 14). The local conditions are those which affect the circulation and the innervation of the part to be repaired. The primary active hyperæmia may be rendered excessive and prolonged, and nutrition be thus disturbed, by an improper position of the injured part or by any impediment to the return circulation. The prolonged application of cold impairs nutrition. Tension in the wound acts by obstructing the flow of the blood in the capillaries, and thus disturbing cell development and formation, a defect in nutrition.

The modifications which these various conditions, separately or in combination, may determine, may be divided according as the disturbances which they provoke result simply in prolongation of the healing and waste of the reparative material, or in arrest of nutrition and necrosis of tissue. The former may still be considered as examples of normal healing; the latter introduce disease into the process of healing, the most common manifestation of which is the condition of *inflammation*.[1] A

[1] It is to be regretted that the term inflammation has been separated by recent pathologists from its traditional use to denote destructive disturbances of repair in

brief consideration must be given to the phenomena which these modifying circumstances introduce into the processes of repair.

Modified Normal Repair.—In injuries in which apposition is imperfect, but in which all sources of further irritation may be avoided and the conditions that favor nutrition can be secured, an apparent modification of the healing process results from the greater amount and extent of the new tissue required to effect repair, but the process is essentially the same. Afflux, exudation, and cell-germination are continued until the gap is filled up; capillary loops are continuously extended into the new material as it is formed, and a progressive transformation of it into connective tissue, beginning in the portions first formed, takes place. Numerous granular eminences appear on the superficial layer of the new material, from the clustering of the new tissue about the capillary tufts. These are *granulations*, in technical nomenclature, and the new tissue is designated as *granulation tissue*. The process of healing thus accomplished is termed *healing by granulation*, or by *second intention*. In open wounds, when the granulations have reached the level of the cutis, or even sooner, they cease to grow; from the adjacent margins of epidermis a proliferation of epidermal cells takes place, which forms a film that gradually spreads over the granulating surface, forming an epidermal covering which completes the process of healing.

If surfaces that are granulating healthily can be brought and retained in contact with each other, prompt and permanent adhesion between them will take place. Union thus obtained is union by *secondary adhesion*, or *third intention*.

The conditions necessary for securing the undisturbed production and organization of granulation-tissue are most frequently secured in subcutaneous injuries, in which cases the integument serves as a protection from further irritation, and especially from that produced by the floating organic matter of the air.

They may also be sometimes secured in open wounds which expose a flat surface by the rapid drying of the substances effused—blood and lymph—on the surface, so as quickly to produce a hard crust that forms a nearly impermeable layer, protecting and sealing up the granulating sur-

---

wounds or tissues, and has been extended to cover, likewise, all the processes which attend the repair of wounds. By the present writer it will be used only in the restricted clinical signification which was given to it by the older writers, and with which it is still used by practical surgeons.

face beneath from further irritation until its cicatrizatio
This constitutes *healing by scabbing*. Though frequent i
open wounds in animals, the greater sensitiveness to irri
by the tissues of man make this method of healing ap
wounds of small extent only. The practical difficult
repair of open wounds is to protect them from irritati
sources of irritation may with care be avoided, the
wound surfaces or in the wound secretions of se
been floating in the air that gains access to it, or
fluids or dressings that are applied to it, usuall
The growth of these germs, under the most favora
duces a continuous irritation of the wound.
irritation, its immediate result is exaggeration
hyperæmia, excessive exudation of plasma, and
onic cells. If the cells be in excess of the nu
organized into the new tissue, they are floate
the granulating tissue, suspended in the liqu
ish, bland liquid that bathes the free surf
pus; the process of its formation constitu
in which it appears is a *suppurating wou*
waste embryonic tissue cast off from a g
perfectly protected from irritation. Its
accompaniment of repair, but it is so
protected so perfectly from all irritati
to be considered as a natural attendant
in which union by first intention is no
as formed, is important to be secu
itself a source of disturbance, by di
the products of its decomposition.
healing the pus becomes thin
exposed to desiccation the concl
quently takes place under a scab.

Suppuration involves waste
and entails delay in the com
ordinary course of the healin
destruction of tissue.

Disposition of Effused
tions of blood, of varying

...pedi-
unbroken
...red parts by
...on, without its
...pair of the injury
...mporarily the appo-
... or in injuries that
... the dead particles or
... decomposition takes
... of the living and dead
... hyperæmia, excessive
... cells. The new-
... and produces thus a
... the dead parts. The
... rapidity with which a
... upon the activity of the
... the separation of bone
... more tardily than that
... the surfaces of a wound
... repair will be accom-
... which have been
... complicated not only
... original violence, but
... impaired, that are half-
... injury, or interferes

an injured part presents as the direct effect of the injury may modify the process of repair. In subcutaneous injuries blood-extravasations, to some degree, are almost always present, and in the great majority of open wounds there remains, at least a slight layer of coagulated blood between the wound surfaces. The cavity of an open wound, in many cases, is filled with blood-clot, like a plug. Blood-clot may hinder repair, both by mechanically preventing apposition and by the irritation of the products of its decomposition and of the development of septic germs, to which it may afford a nidus for multiplication. In subcutaneous injuries blood-clots neither decompose nor become invaded by septic germs. When the blood is infiltrated into the connective-tissue meshes it is quickly removed by absorption; when it remains as a mass filling up a gap between divided tissues it serves as a temporary mould for the support of the new embryonic tissue that is to form the permanent bond of union. The granulation cells produced at the borders of the divided tissues invade and appropriate its substance, capillary vessels follow the invading cells, and a process of clot-absorption and granulation-tissue development continues until the clot has disappeared and has become replaced by cicatricial tissue. In open wounds, when apposition of the divided surfaces can be secured and maintained, any slight film of blood-clot that may be present will not perceptibly interfere with the repair, but will be quickly appropriated by the germinating tissue-cells, and will disappear. In open wounds, in which union by first intention is impracticable, if the access of septic germs can be prevented the behavior of the clot is the same as in subcutaneous wounds. The process of its invasion and replacement by granulation-tissue gradually extends toward its surface, till, after some days, what appears to be the clot will bleed when scratched. More frequently the superficial layer of the clot remains as a somewhat dried, dark-colored stratum, that is not invaded by the granulation-tissue, but acts as a protective shield to the deeper parts and is finally exfoliated, scab-like, when the cicatrization of the tissue underneath is nearly or quite complete. In open wounds which are not kept aseptic—and these constitute the vast majority of wounds—the blood-clot decomposes, liquefies, and is washed away in the discharges from the wound.

In all wounds there is devitalized tissue that must be taken care of. The removal of all dead tissue, when undisturbed by external agencies, is accomplished by the same processes of cell-invasion and appropriation as has been described as the active agents in the disposal of blood-clots.

The minute particles of dead tissue which exist along the track of an incised wound, or at the seat of a mild contusion, are quickly absorbed, and do not perceptibly interfere with the repair of the injury. Larger masses, likewise, if they can be kept from decomposition, and thus from becoming irritants, may be gradually removed by the same process and their place taken by new tissue. Inasmuch as the active agents in the production of decomposition are minute germs that float in the atmosphere, the exclusion of these germs from access to the dead tissue is of the first importance in promoting repair of all injuries. When the amount of dead tissue is very small, and the other conditions for active repair are supplied, as in incised wounds in which apposition, proper nutrition, and freedom from irritation are secured, the constructive power of the living tissue is sufficient to resist the destructive tendency of the germs that may have gained access to the dead molecules, and no impediment to rapid repair is suffered. In subcutaneous injuries, the unbroken skin forming a perfect barrier against the infection of the injured parts by external organisms, the removal of dead tissue by absorption, without its becoming a source of irritation or complicating the repair of the injury in any other way than by mechanically preventing temporarily the apposition of living parts, is the rule. In open wounds, or in injuries that have become such by death of the skin, infection of the dead particles or masses and their conversion into irritants through decomposition takes place. The reparative efforts at the line of junction of the living and dead tissue are characterized by undue and prolonged hyperæmia, excessive exudation of plasma, and over-production of embryonic cells. The new-formed granulation tissue breaks down into pus, and produces thus a solution of the continuity between the living and the dead parts. The dead part thus cast off is called a *slough*. The rapidity with which a slough may be completely cast off will depend upon the activity of the natural nutritive processes of the particular tissue ; the separation of bone or tendon, for example, being accomplished much more tardily than that of muscle or ordinary connective-tissue. When the surfaces of a wound have become thus freed from dead tissue, its final repair will be accomplished by granulation with suppuration. Injuries which have been accompanied with much crushing and tearing are complicated not only by the presence of parts killed outright by the original violence, but also by portions of tissue whose vitality is greatly impaired, that are half-killed. Whatever adds to the irritation of the original injury, or interferes

with the after-nutrition of these half-killed parts, endangers still more their vitality, and their absolute death may be determined by such subsequent conditions at any period of the reparative process. In subcutaneous injuries, and in open wounds that are kept free from septic infection, the gradual return of these half-killed tissues to their normal state takes place, and the repair of the injury is accomplished without the separation of any slough.

A review of the processes of normal repair which have been described shows that, when uninterrupted or unimpaired by external agencies or by unhealthy constitutional conditions, they are competent to remove dead tissue, to restore vitality to partially killed tissue, to furnish new material to repair breaches of continuity, and to accomplish the complete reorganization of this new material into living tissue. In the less favorable conditions which those open wounds present in which the access of atmospheric organisms and the sloughing of dead tissue is unavoidable, as long as the free escape of the decomposing particles and of the pus is possible, and further injury by external agencies or by unhealthy constitutional conditions is avoided, uninterrupted repair still takes place, but with the waste of much reparative material, which escapes as pus from the exposed surfaces.

Though the processes by which repair is effected are identical in all these conditions, the practical results are very different according as repair is effected without or with suppuration. When repair without suppuration is accomplished, a minimum amount of new tissue is required, a minimum disturbance of the nutrition and the function of the injured part is suffered, and the most speedy return of the organ to its functional activity is secured. When suppuration attends repair the process of healing is prolonged, a greater drain upon the bodily powers is produced, prolonged disturbance of the nutrition and function of parts is suffered, and throughout danger of disaster from accidental complications is imminent. When repair is finally accomplished the new tissue is less highly organized than that which it has replaced and permanent impairment of the function of the part is frequent.

Destructive Disturbances of Repair.—The turning-point where the processes of normal repair become converted into processes of necrosis is the occurrence of prolonged stasis in the capillaries of the wound margins. By repeated or prolonged irritation of the already injured tissue—the lower the vitality of the tissue the less the irritation needed—the area

of the primary active hyperæmia is increased, while a gradual slowing of the blood-current takes place in the vessels which are nearest to the point of irritation, until finally it ceases altogether, although at the periphery of the disturbed region the conditions of vascular dilatation and of accelerated blood-flow continue. Simultaneously with the retardation the white corpuscular elements of the blood—leucocytes—begin to crowd in numbers against the walls of the capillaries, and to penetrate them by their amœboid properties, and to accumulate in the perivascular tissue. An increased transudation of liquor sanguinis also takes place, and when stasis finally occurs the vessels remain choked with a crowded mass of red-blood disks. These conditions declare themselves by increased redness, heat, swelling, pain, and impairment of function in the affected part, and by more or less fever. A part presenting these symptoms is said to be inflamed, and the condition, as a whole, constitutes *inflammation.*[1]

When stasis has occurred the death of the tissue involved is imminent, but if further injury is averted and the general conditions favorable to repair are furnished the stasis may shortly be overcome and the natural course of the circulation be resumed; *resolution* of the inflammation has been effected. If, however, irritation be renewed or continued the stasis is prolonged and local death, or *necrosis* of tissue takes place.

Inflammation of a wound involves, therefore, not only arrest of normal repair, but additional destruction of tissue; granulation is replaced by ulceration, and a new element of disturbance is introduced by the dead tissue which is to be eliminated. In the treatment of a wound, it is important that inflammation be prevented, or that, if it be present to any degree, its resolution be gained, and its destructive effects be limited. Inflammation is always due to some "defect of protection" (see page 28). When a wound is inflicted upon a tissue, the injury is done at once; the extent and duration of the nutritive disturbances that follow are limited by the extent and character of the immediate injury, and they do not reproduce themselves in adjoining healthy tissues, except as the result of new injuries. The agents of injury may be gross or minute, may produce their effects through mechanical violence or by chemical action, may be microscopic germs or subtle poisons, but they all have the common effect of impairing the vital quality of—*i.e.*, injuring—the tissues they come in contact with. The practical fact, however, is always to be borne in mind,

[1] See note on p. 28.

that the effect of any particular injury will always be greatly modified by the pre-existing condition of the tissue acted upon, and of the inherent resisting quality which it may possess. While inflammation is present, the healing of a wound is arrested, and if it supervene in a wound in which agglutination has already taken place, the new-formed bond melts down and the wound gapes, presenting red, swollen, and everted edges. The local diseases of wounds—erysipelas and gangrene—and the general blood states that are dependent upon wounds—pyæmia and septicæmia—have a common initial lesion in wound-inflammation.

To prevent or to limit inflammation, or to lessen the effects of the disturbances induced by it, appear, therefore, to be indications of the greatest importance to be met in the treatment that a wound shall receive. The conditions of inflammation, however, do not arise spontaneously, nor do they perpetuate themselves. The continuance or the extension of an inflammation results only from the continued or extending action of some irritant. The more gross irritants, as motion, friction, or other mechanical violence, or ordinary chemical agents, are readily detected, and, usually, as easily guarded against. In the remarks upon classification of wounds, the difference in the behavior of subcutaneous and open wounds, as regards their liability to inflame, was mentioned, and the inflammatory disturbances likely to result from the access of ordinary air noted. "Of the two injuries inflicted in a wound, the mechanical disturbance of the parts and the exposure to the air of those that were covered, the exposure, if continued, is the worse. Both are apt to excite inflammation; but the exposure excites it most certainly, and in the worse form; *i.e.*, in the form which most delays the process of repair, and which is most apt to endanger life" (Paget). It was still further noted that so great was the difference between the behavior of wounds in which there was much devitalized tissue left behind by the wounding agent, and those in which there was little, that it constituted a basis for important clinical classification. That the mere presence of devitalized tissue alone is not the cause of these disturbances, however, is shown by the fact that similar injuries, if subcutaneous, escape them in great measure. The mere presence of ordinary air alone is not the cause of these disturbances, as is shown by the harmlessness of surgical emphysema, and the freedom from injury exhibited by animals through whose peritoneal cavity unfiltered ordinary air has been passed for hours. The only conclusion is that, in the cases in question, the cause of inflammation, and of the

wound-diseases that are associated with it, is to to be found in the mutual reaction of devitalized tissue and some agent present in the air. Wound-secretions, when accumulated in excess of that which can at once be converted into living tissue, and blood-clots, are but forms of devitalized tissue, and display the same reaction with atmospheric agents. The importance, therefore, of securing the most complete removal of blood-coagula and of wound-secretions from wounds that are to be left exposed to the air, depends more upon the inflammation-producing reaction which they will suffer with agents brought in contact with them by the air, than it does by the defects of apposition which they produce. Simple defects of apposition, as has been seen, entail only prolonged repair; the decomposition of devitalized tissue, of blood-clots, and of wound-secretions introduce continuous and active local irritation, and bathe the tissues with products, the absorption of which into the circulation poisons the very fountain of life.

The inflammation which complicates the repair of open wounds manifests varying degrees of intensity, and of tendency to extend in different cases. It may be limited to but a small extent of tissue adjacent to the wound-margins, and, with the separation and removal of the shreddy sloughs formed by the dead particles of tissue originally in the wound, and of the liquified blood-clots, or by the escape of the accumulated secretions, may quickly subside and permit the resumption of the healing of the wound by granulation. It may diffuse itself upon the skin, forming a superficial erysipelas, or may extend more deeply along the planes of connective tissue that may have been opened up by the wound, constituting a diffuse cellulitis or a phlegmonous erysipelas. The amount of necrosis also may present every grade of extent from that of molecular disintegration upon the surface of the wound to the death of large masses of tissue. The amount of constitutional disturbance produced by the absorption of matters generated in the inflamed tissue varies likewise from a slight ephemeral febrile reaction to fatal septicæmia and pyæmia. It is not in the scope of this work to discuss in detail the various phases of the destructive disturbances which may complicate wounds. Sufficient only can be presented to serve as a groundwork upon which to base a rational and comprehensive preventive treatment, for the treatment of a wound cannot be considered as accomplished until all the possible safeguards against the disturbance of its repair have been secured.

CHAPTER III.

THE RELATIONS OF MICRO-ORGANISMS TO WOUND-DISTURBANCES.

Results of Defects of Protection—Causes of Decomposition of Animal Tissues—Researches of Pasteur and Tyndall—Atmospheric Organisms—Resisting Power of Living Tissues—Species and Generation of Micro-organisms—Bacteria—Bacilli—Micrococci—Researches of Ogston, Koch and others—Views of Hunt—Summary—Wound Suppuration—Septicæmia—Pyæmia—Micrococcus-poisoning—Clinical Demonstrations—Results of the Practice of Lister, Volkmann, and Nussbaum—Comparative Statistics of Amputations—Macewen's Osteotomies—Testimony of Sands, Stokes, Cheyne, and Little—Résumé.

The importance of the considerations which have been under review in the preceding chapter, as to the mechanism of healing and of the disturbances that may complicate it and convert its beneficent constructive processes into those of local embarrassment and death, and of possible general danger, have their greatest demonstration in the aid which they have given in directing a search for the ultimate causes of the changes that result in disorders of repair. Only with accurate knowledge of these causes can intelligent effort to prevent their access, to destroy them, or to make them harmless be made. Without such knowledge wound-treatment is an empirical groping; with it, it becomes an exact science. It has been seen that defects of reparative power, constitutional and local, may hinder repair; that defects of apposition prolong repair and occasion waste of reparative material, but that in defects of protection are found the conditions that produce arrest of repair and destruction of tissue; that the defects of protection which occasion the most frequent and most serious wound-disturbances are those which permit the access of atmospheric air to wounds; that those wounds manifest these disturbances in the highest degree which present the largest amount of devitalized material; and, finally, that, with the exception of the transient inflamma-

tions due to repeated traumatism, the various inflammatory and septic accidents that wounds suffer are due to wound-decomposition.

The causes of the decomposition of animal tissues, and the laws, methods, and products of their activity, must therefore be regarded by the surgeon as matters of fundamental importance in all considerations as to the treatment which he shall give to wounds. As to the causes of decomposition in animal tissues, they are of the same general character as those which determine decomposition or fermenting changes in organic matter of any kind. The researches of Pasteur, of Tyndall, and their co-laborers, have clearly and definitely settled the scientific truth that no decomposition or fermenting change will take place in organic matter, except after the introduction into it from without of living organisms that find in its substance pabulum meet for their nutrition, and, as the result of their multiplication within it, induce its decomposition. The most frequent and universal medium by which these organisms or their germs are brought in contact with material susceptible of decomposition is the ordinary air, in which they are found as a part of the organic matter that constitutes most of its floating dust. Even the most putrescible substances, as urine, and animal and vegetable infusions, remain unchanged for an indefinite period when they are kept in an atmosphere which is purified from organic particles. It is not the fully developed organism that is found in the floating matter of the air, but minute spores or germs that require to be planted in a proper soil, and to be surrounded with certain favorable accessory conditions for their germination and growth into the fully developed organism to take place. The matters secreted by them in their development, or the changes inaugurated by their vital activity as living organisms, determine the changes in the substances in which they multiply which constitute decomposition, putrefaction, and fermentation.

Such germinal particles "abound in every pool, stream, and river. All parts of the moist earth are crowded with them. Every wetted surface which has been dried by the sun or air contains upon it the particles which the unevaporated liquid held in suspension. From such surfaces they are detached and wafted away, their universal prevalence in the atmosphere being thus accounted for. They are endowed with a power of flotation commensurate with their extreme smallness and the specific lightness of the matter of which they are composed" (Tyndall).

Since these agents of decomposition are particles and not gases, they are not uniformly diffused through the atmosphere, but are likely to be

more numerous wherever and whenever the conditions that favor their growth and dissemination are active.[1] This implies the contrary truth also, that at times, and in certain conditions that promote purity of the atmosphere, indefinite volumes of it may be free from septic germs altogether. Particular germs of the same species differ also as regards their readiness for development; some are fresh, others old; some are dry, others moist. The conditions which modify the germination of gross seeds affect in an equal manner these minute germs. The external conditions of warmth and moisture hasten their development; cold and absence of moisture retard it. Of the greatest importance, however, from its power in limiting their disease-producing effects, is the power with which the living tissues of the body are endowed of resisting to a certain extent the action of these germs, and of destroying them. As a consequence of this these organisms are never found in the fluids or tissues of the healthy living body, notwithstanding they abound in the air by which it is encompassed; they rest and develop in the secretions that issue on the surfaces and gather in the depressions of the external covering of the body, and they swarm in the secretions and contents of the alimentary canal. To this resisting power in living matter is due the fact that those germs which may have gained access to the tissues exposed by a wound, do not develop and multiply and produce decomposition in such a wound when speedy and complete contact of its surfaces is secured and maintained. On the contrary, whatever germs may be present in such a wound are killed by contact with the living cells that are active for its repair. Should, however, the coaptation of the wound-surfaces be imperfect, so that recesses or cavities remain in which fluid exudates accumulate, the best of conditions are afforded at once for the development of whatever germs might have gained access to them.

---

[1] M. Miquel's experiments at the observatory at Montsouris in Paris, show that they are most numerous in the lower strata of the air. While in a cubic metre of air at the top of the Pantheon he found but twenty-eight of them, the same quantity of air in the park of Montsouris contained forty-five, and in the mairie of the fourth arrondissement, four hundred and sixty-two. Great agglomerations of men furnish the most of them. The air in the interior of Paris is nine or ten times richer in them than that in the neighborhood of the fortifications. The dusts proceeding from substances in a state of putrefaction, unhealthy pus, and the dejections of the sick, are charged with them. After two or three days of moist and rainy weather, the atmosphere is in a condition of extreme purity.

Much still remains to be determined with regard to the disease-producing possibilities of the germs that in invisible clouds drift in the atmosphere. We are as yet only on the threshold of knowledge with regard to them. The extreme minuteness of the organisms themselves, and the still more minute character of the germs by which they are disseminated, make their isolation and study one of great difficulty, and one especially liable to errors. The more delicate and exact methods of the most recent observers—Koch, Pasteur, Tyndall, Ehrlich, Ogston, Sternberg, and others —with regard to their nature, seem to show that there are many species of them, each of which has its own conditions of growth, requiring, or developing best in, a particular soil, different species multiplying in different media, and varying in their susceptibility to different temperatures and to different chemical reagents. Apparent identity of form does not necessarily indicate identity of nature. They are not convertible into each other; each species produces only itself, and is produced by itself alone, and, when introduced into a substance that affords a favorable soil for its growth, always produces in it the same results. These results are not produced suddenly, but are of gradual development, progressing *pari passu* with the slow and steady multiplication of the organism. In addition to the immediate and direct effect of the multiplying micro-organism, chemical changes, for the inauguration of which the organisms were necessary, after having been once set in motion by them, may continue to advance after the activity of the organism has ceased.

The species of micro-organisms that have been identified as capable of producing disease in the human body are comparatively few in number. Of these, the ones that are concerned in the production of the inflammations and infectious diseases that complicate wounds are embraced in two great groups, viz.: spherical organisms, or *micrococci*, and rod-shaped organisms, which include *bacteria*[1] and *bacilli*, the term bacteria being applied to slightly oval or sausage-shaped organisms, and bacilli to the more slender rods. The characteristic appearance of these forms is well shown in the accompanying cut (Fig. 1), in which all three forms appear as present in the discharges from a case of compound dislocation of the thumb, in which no attempt to prevent their development had been made (see Cheyne, "Antiseptic Surgery," p. 235, Case 1).

---

[1] The term *bacteria*, though originally applied to all forms of micro-organisms, has become restricted to the special form noted in the text.

The conditions in which these different forms of organisms flourish differ, and the results, in general, determined by them also differ. In every wound which smells suspiciously the rod-shaped organisms are present in large numbers. Where a bagging wound or a deep sinus is present, the discharge is apt to be fetid and contains mostly the rod-shaped organisms; but when an incision converts the pouch into a superficial wound, the spherical organisms again become predominant (Ogston[1]); and in the discharges which flow from flat surfaces in general, where stagnation is avoided, the spheres exist in preponderating numbers. The conclusion is that the character of the decompositions determined by the growth of

FIG. 1.—The Micro-organisms of Septic Wound Discharges (enlarged from *Cheyne*).

these different micro-organisms are not identical, but that each, in feeding on the soils in which they are sustained, generates different changes in the substances where they grow. The bacteria as a class, and some bacilli as well, produce the decompositions of putrefaction, *i.e.*, those in which the substances evolved have an offensive stench. If the contents of an abscess, or a fluid where organisms have been growing be found to present a putrid smell, we are absolutely certain to detect in it numerous organisms that possess either the sausage-shape of the bacterium or the rod of the bacillus (Ogston). The more putrid the discharge the more numerous and the smaller the bacteria (Cheyne). The vital energy of these or-

[1] Report upon Micro-Organisms in Surgical Diseases. By Alexander Ogston, M.D. British Medical Journal, March 12, 1881.

ganisms of putridity is weak; they are quickly killed by weak antiseptic agents; they do not survive, much less grow in the blood; they do not invade living tissue, but attack only dead tissue, and when they affect the general system it is by the absorption into the blood of the putrid liquids and gases that are generated at the original site of putrefaction. The septicæmia that is produced depends for its continuance upon the continued activity of the local putrefactive process, and disappears when this external supply is stopped. Wounds containing much putrefiable material, when they are at the same time of such a character as to hinder the ready escape of the wound-secretions, afford the most perfect conditions for the luxuriant development of these organisms. The removal of sloughs, the opening of sinuses, and the establishment of free outlets for the secretions, tend to banish the organisms by removing the pabulum necessary for their existence.

The spherical organisms—micrococci—manifest characteristics quite different from those displayed by the rod-shaped, and exhibit a relation to wound-disturbances much more extended and difficult to control. Micrococci are described by Cheyne as colorless or colored round cells, very small, generally under one micro-millimetre in diameter, with or without movement, growing in pairs, short chains, or groups of smaller or larger size, this cycle being repeated on the addition of fresh pabulum. In a given specimen of pus they will not be uniformly distributed, and they will vary in size, while in different specimens their numbers may vary greatly. One specimen of pus examined by Ogston contained forty-five millions per cubic millimetre, while two others contained in the same bulk only nine hundred. The decompositions that they induce are not those of common putridity. If they are introduced into a fluid and there cultivated they produce no offensive stench. In most acute abscesses where they abound no bad odor is detectable, and in general their presence or absence is not indicated by any smell. The observations of different investigators indicate that there are different species of micrococci, some comparatively innocuous, others extremely virulent. "Some are pathogenic and others are not; some develop in the blood of certain animals and others will not. Different species multiply in different media, and are destroyed at different temperatures. A nutrient medium which has been exhausted for one micrococcus may not be exhausted for another" (Sternberg). Cheyne describes certain micrococci as existing in wounds, even in large numbers, without apparent ill effect beyond causing a sort of

sour, sweaty smell in its fluids. Ogston found micrococci in the pus of all acute abscesses, and in wounds, in amount and activity proportionate to the intensity of the suppuration; but a marked difference was found to result in the results of injections made into the tissues of mice with the pus of abscesses and the pus of wounds. With the first, with rare exceptions, well-marked disease, either rapidly fatal blood-poisoning, or local sphacelus, or acute inflammation, accompanied by blood-poisoning and

FIG. 2.—Group of Chain Micrococci (*Ogston*).

ending in abscess, followed. With the latter, that of wounds, though rich enough in micrococci, it was with difficulty that an occasional suppuration was produced. This observer further describes[1] two distinct forms of micrococci, among the more virulent organisms, chains and groups (Figs. 2 and 3), which though often found together, were different organisms; the chain form never passing into the grouped form, nor the grouped form into the chain. Both possess the power of causing inflammation ending in suppuration, and both cause phlegmons. But the more disease approaches the erysipelatous type and concentrates itself in the lymphatics, the more evident does its connection with the chain form become; while suppurative inflammation, expending itself on the tissues rather than on the lymphatics, seems to be the characteristic result of the grouped form. Fehleisen, of

[1] Micrococcus Poisoning. By Alexander Ogston, M.D. Journal of Anatomy and Physiology, vols. xii. and xiii.

Berlin, has demonstrated by direct proof the agency of chain micrococci in the production of erysipelas. This observer not only found them present in all cases of erysipelas which he examined during life, but also cultivated them, and with equal success inoculated the cultivated organisms in animals and in man.[1] By planting small pieces of the excised erysipelatous skin in gelatine, he inaugurated a series of cultivations, by

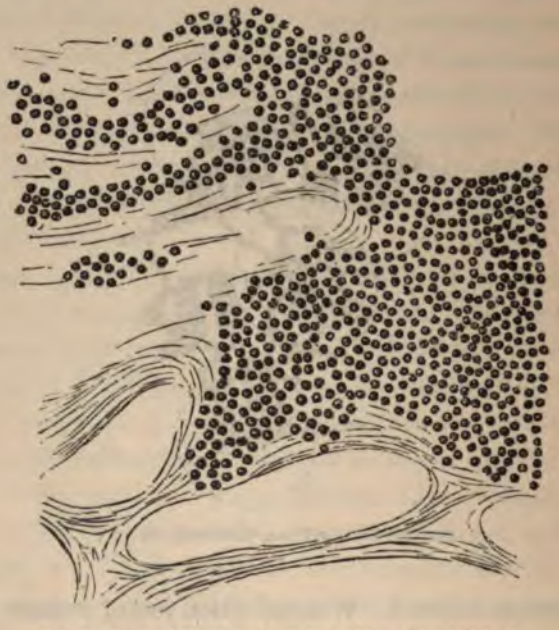


FIG. 3.—Grouped Micrococci invading Abscess Wall (*Ogston*).

which films consisting entirely of the specific micrococcus were obtained. Of seven men whom he inoculated with the micrococci thus isolated, six showed, after a period of incubation ranging from fifteen to sixty hours, typical erysipelas, setting in with rigors, high temperature, and running the characteristic course.

Koch[2] describes a micrococcus that whenever it was introduced into the tissues of mice produced a spreading gangrene that extended continuously until it killed the animals. The inflammation, suppuration, and

[1] Die Aetiologie des Erysipels. Berlin, 1883.

[2] Investigations into the Etiology of Traumatic Infective Diseases. By Dr. Robert Koch (Wollstein). Translated by W. Watson Cheyne, F.R.C.S. London: The New Sydenham Society, 1880.

gangrene produced by micrococci cannot with reason be referred to any mechanical effect from their presence. Koch explains the gangrene-producing effects of the organisms investigated by him, as follows: "Introduced by inoculation into living animal tissues, they multiply, and as a part of their vegetative process they excrete soluble substances which get into the surrounding tissues by diffusion. When greatly concentrated, as in the neighborhood of the micrococci, this product of the organisms has such a deleterious action on the cells that these perish, and finally completely disappear. At a greater distance from the micrococci the poison becomes more diluted and acts less intensely, only producing inflammation and accumulation of lymph corpuscles."

Ogston, likewise, concludes that it must be by the noxious substances generated during their growth that they irritate the tissues, and cause inflammation and suppuration. "It may be looked upon," he says, "as being far from unlikely that the very reason why micrococci produce suppuration is that they, in growing among the tissues, generate some acrid ptomaïnes that may correspond pretty closely in their effects with those of injections of turpentine or other caustic liquid."

Belfield,[1] after referring to the experiments of Pasteur, in which a previously harmless culture fluid, when it had become swarming with micrococci by the multiplication within it of a micrococcus found in ordinary water, was invariably followed, in the rabbit, by suppuration around the point of injection, the pus and tissues containing numbers of the same organisms; and to the observations of Klebs, Zahn, and Tiegel, who found that while the injection of pus from a pyæmic abscess or putrid fluid was followed by local suppuration and multiple abscess formation in the infected animal, the same pus or liquid, after filtration through clay cylinders—whereby the micro-organisms were separated from the liquid—caused intense general infection, but no suppuration, even at the point of injection; and to the observation of Koch that infectious suppuration in the rabbit after putrid inoculation was constantly associated with a characteristic micrococcus, says: "It appears, therefore, impossible to evade the conclusion that suppuration can be, and is induced by micrococci. That this effect is induced by one or more specific varieties of these organisms seems probable from these researches of Klebs, Koch, and Pasteur;

[1] On the Relations of Micro-Organisms to Disease. By William T. Belfield, M.D. The Medical Record, March 3, 1883, p. 228.

that it is not induced by *all* species is apparent from the fact that colonies of micrococci are frequently present in the human and other animals during various morbid processes in which suppuration does not occur—as in erysipelas. As to the mode in which this influence is exerted, there is no definite knowledge ; the assumption that the deleterious effect results from changes in the chemical constitution of the containing medium, as an essential feature of the vital activity of these organisms, is supported by analogy with the processes of fermentation and putrefaction, by the phenomena known to attend the life of other bacteria, and by the direct observations of Koch and Pasteur."

The relation of micrococci to suppurative inflammations is one of great interest and importance in its bearing upon the healing of wounds. While —as has been seen—not all forms of micrococci are capable of exciting suppuration, nor are micrococci the only agents that are competent to excite suppuration, yet the proof seems strong that the suppurations and suppurative diseases that complicate wounds, and the acute suppurative inflammations that occur in man are caused by the vital activity of some form of micrococcus. The observations of Ogston, in which the presence of micrococci in the pus of all acute abscesses, and in that formed in wounds, have already been referred to. The negative observations of the same investigator are also to be considered with these, that in wounds in which no micrococci could be discovered, no pus was produced, but the discharge remained serous ; and that in all cases in which, by his method of dressing wounds, the access of micro-organisms from without was guarded against, both micrococci and suppuration remained absent. When, however, wounds suppurated, the intensity of the suppuration was proportionate to the numbers and activity of the micrococci, which not only multiplied in the wound-secretions, but also infiltrated the adjacent tissues, until, by the formation of a dense layer of granulation-tissue, their further invasion was limited. The chain of proof that the micrococci are the essential causes of the suppuration is rendered nearly complete by the results of inoculation experiments, by which it has been shown that pus devoid of organisms, as in that of chronic abscesses, or pus whose organisms have been killed by carbolic acid or high temperatures, is harmless when injected into the tissues of animals, while pus that contained micrococci, when injected, in doses of a minim or more, invariably occasions well-marked disease, comprising, as a general rule, acute local inflammation accompanied by blood-poisoning and ending in abscess.

The experimental proof is continually accumulating that the various inflammatory disturbances that embarrass the healing of wounds are due, with but few—and these easily recognizable—exceptions, to the results of the vital activity of micro-organisms. Nevertheless, many still demur that the proof is not sufficiently positive that the organisms are the specific and primary cause of the irritation that determines the inflammatory disturbances, but that a possibility exists that, after all, they may be simply the concomitants of conditions that have determined the inflammation, conditions the exact character of which has as yet eluded our search. Perhaps no better putting of such objection has been phrased than that of Dr. William Hunt, Senior Surgeon to the Pennsylvania Hospital, in the address delivered by him before the Philadelphia Academy of Surgery, January 8, 1883. In this address he speaks as follows:[1] "Now, are the plaguing micro-organisms, of which we hear so much, any more than consumers of dead material, serving (as we find them everywhere) a beneficent end so long as they do not get into the *wrong* places? Molecular death is going on continuously in all living tissues. In the nice balance of perfect health, the results are removed so completely through the blood and lymph channels, and by other means, that there is no accumulation. When, however, disturbances arise, as inflammations, for example, from any cause, abundant *necrotic* products are the conseqnence, and these accumulate faster than they can be removed. Then come in the migratory micro-organisms. It is a question of food, and is consonant with what we know of the movements of hosts of higher animals, possibly also of plants, and sometimes of man himself. As these organisms get into the *wrong* places, they, accumulating with great rapidity, help to choke further and irritate what has already started on an evil course, and so they become secondary and very fruitful causes of disease."

In this view, so attractively and ingeniously set forth, of the relation of micro-organisms to wound disturbances, the relation of the micro-organisms to the changes in the necrotic products, by which these become inflammation-producing agents, is lost sight of, and the only evils recognized as resulting from the presence of the micro-organisms are those simply which the accumulation of the organisms themselves in wrong places may be capable of determining. The sequence of events which is claimed is: 1, inflammation, from some cause; 2, accumulation of ne-

[1] Medical News, p. 93, January 27, 1883.

crotic products; 3, micro-organisms. If we test this order by the sequence of events which occur in a wound that has become inflamed, in which case the causes of the inflammation may be followed accurately with more ease than in the case of internal inflammations, the error of the view becomes apparent.

In the case of a wound, the injury sustained by the wounded tissue does not involve new tissue after the injuring agent has ceased its action. The tissues in which vitality remains proceed at once to efforts at repair, which process, modified in its activity only by the local and constitutional vigor of the individual, progresses regularly to its termination, provided new sources of injury are not added. The presence of the devitalized tissue, resulting from the original injury, embarrasses the process of repair only mechanically until it is absorbed, or otherwise removed, as long as it is preserved from putrefactive changes. Putrefaction results, and results only, from the introduction into the devitalized tissue of such micro-organisms as find in it a suitable medium for their active growth and multiplication. As a result of their action the devitalized tissues become irritants that add new and continuously acting injury to the parts with which they are in contact, the final outcome of which is the condition which a surgeon terms inflammation—a condition which will persist and spread until in some way the source of irritation is eliminated or isolated. The case, then, as observed in wounds, may be summed up briefly somewhat in this way: Inflammation is always the result of continued irritation; devitalized tissue, in itself, in whatever quantities, is unirritating; therefore the accumulation of devitalized tissue is not a cause of inflammation. Devitalized tissue in which micro-organisms are growing and multiplying is irritant, and prone to excite inflammation; the new and specific element which has been added, and from which the irritant qualities spring, are the micro-organisms; therefore, from the point of view of the inflammation, they are its specific and primary cause. The order, therefore, of the sequence of the conditions which determine inflammation in a tissue is not that of the author to whom reference has been made, but is the exact reverse, viz.: 1, micro-organisms; 2, necrotic products; 3, inflammation.

It is hardly necessary to observe that this discussion applies equally to the causes of the suppuration which usually accompanies the healing of wounds by granulation, for the production of pus upon a wound surface is the result of irritation of that surface, and depends for its continuance upon a condition of the tissues alike in kind, and differing only in degree

and extent from that which constitutes inflammation, in the surgical sense of the word. The products of the ordinary micrococcus, as it multiplies in the secretions of a wound on whose surface it has been deposited, are but little irritating, as has been shown by its feebly noxious effects when injected into the tissues of living animals; but it is sufficient to provoke the prolonged hyperæmia, the overflow of plasma, and the excessive production of cells that constitute suppuration.

Thus far in the consideration of the relations of micro-organisms to wound-disturbances, a brief outline only of the knowledge which has thus far accumulated as to their local effects has been attempted. It has been seen that positive proof has been furnished that in many cases suppuration, phlegmonous inflammation, gangrene, and erysipelas have been the direct result of the vital activity of certain forms of micro-organisms, and that a strong presumption has been established that the same relation of cause and effect existed in general. Incidentally reference has been made to the effects produced upon the whole system by the absorption into the blood of the noxious products or ptomaïnes that result from the changes in the pabulum upon which they feed, to which the general term *Septicæmia* is applicable. This demands farther consideration, and also the closely allied state in which, with a septic condition of the blood, there is associated multiple abscesses in various organs of the body, *Pyæmia*.

Blood-poisoning and metastatic abscesses claim recognition as the most redoubtable processes that can complicate the healing of wounds. Their close association with faults of repair in wounds, and the development of unhealthy conditions in the wound-secretions have always been too distinct to fail of recognition, so that the clinical fact that these processes were consequent upon the absorption of noxious or septic matters produced in the wounds, was long appreciated before experimental investigation attempted to determine and isolate the essential cause of their hurtful character. Belfield, in his lecture on sepsis and antiseptic surgery,[1] gives a summary of the experimental researches that have been made as to the nature and method of working of the septic elements, the more important results of which are those obtained by Panum, Billroth, Bergmann, and others, which established the fact that the clinical and anatomical features of septicæmia could be induced by unorganized substances obtained from the products of putrefaction, though in these cases two character-

[1] The Medical Record, March 3, 1883, p. 225.

istics, frequently observed in the septic infection of human subjects, were often conspicuously absent—the stage of incubation and the infectiousness of the septic blood and tissues; those of Klebs, by which it was shown that the injection of putrid liquids containing myriads of micro-organisms was followed by continuous fever and metastatic abscesses, while the injection of the same liquids after they had been deprived of their solid particles, including organisms, by filtering through clay, was followed by fever just as intense, though transient, but never by metastatic abscesses; those of Pasteur, in which, in animals that had become septically infected, there were always found present micro-organisms in the serous sacs, muscles, liver, and spleen, although the blood may have been free from them until death—a drop of peritoneal serum, or a piece of muscle from an animal dead of sepsis induced in a second animal all the appearances, ante- and post-mortem, of the original disease, while a drop of blood from the heart-cavity, proven microscopically to contain no septic vibrios, was innocuous; and the crowning experiments of Koch, Gaffky, and Löffler, in which the particular bacilli of septicæmia in mice, micrococci of spreading gangrene in mice, bacteria of septicæmia in rabbits, and micrococci of pyæmia in rabbits, were completely isolated from the animal tissues by cultivation upon solids, and, thus isolated, reintroduced into healthy animals with the reproduction of the same diseases as that which had before been produced when the original infected blood was inoculated. The author from whom we quote sums up the case as follows:

"A review of the evidence already considered shows, then, that infectious diseases, identical in clinical and anatomical appearances with the various forms denominated septicæmia in man, have been induced in the mouse and rabbit by inoculation with animal tissues in various stages of putrefaction; that the resulting infection is just as certain if the putrid substances be previously boiled and thereby deprived of living organisms. On the other hand, it is certain that *per se* innocuous culture fluids—infusions of beef, etc.—acquire, after inoculation with minute quantities of infected blood or tissue, the same septic properties, provided such blood or tissue contain living bacteria; it is further certain that this multiplication of the septic substance in such liquid is a concomitant of the vital action of the organisms therein contained; it is further demonstrated that these organisms can and do, not alone multiply the septic material, but when isolated by successive cultures from all the accompanying animal tissues, induce, independently, fatal infectious diseases. The same principle—

vital activity of bacteria—pervades all these phenomena; for the artificial induction of septic diseases has been, in all these experiments, originally accomplished by the incorporation into the animal of *putrid tissues*, with or without bacteria. Now, since putrefaction must be regarded, in the present state of our knowledge, as impossible without the presence of these organisms, it is evident that sepsis, putrid infection, was in every case due, directly or indirectly, to the action of bacteria; since even the boiled substances used by Panum and Rosenberger, and the sepsin obtained from rotten yeast by Bergmann and Schmiedeberg, had acquired their septic properties through putrefaction, *i.e.*, through the action of bacteria. Hence we are logically driven, by all this work, to the belief that septicæmia implies the introduction into the animal either of living bacteria, or of a substance which has acquired noxious properties through previous vital activity of these organisms."

The experiments and observations of Ogston, to which reference has been made in connection with inflammatory disturbances of wounds attended with suppuration, led that observer to the conclusion that septicæmia, pyæmia, and septico-pyæmia are one and the same disease, and that their sole and invariable cause is *micrococcus-poisoning*.

Pus containing micrococci, obtained from an acute human abscess, when injected by this observer into the tissues of mice, in amounts of half a minim or more, produced symptoms of blood-poisoning lasting from two to five days, during which time micrococci could be detected in the blood in the heart; the site of the injection displayed a red infiltration, in which appeared micrococci invading the neighboring tissues, penetrating between their cells, and in colonies or chains, gradually decreasing in size, pushing their way for a considerable distance into the structures in the vicinity. In the centre of this infiltrated region would be an abscess. The micrococci in the heart blood were comparatively few, and somewhat variable in number. Their distribution did not appear to be uniform throughout the blood, and their presence was never detected in the lungs, liver, spleen, kidneys, lymphatic glands, or suprarenal capsules. After five to seven days had elapsed, and in some cases even earlier, the animals exhibited a change. They became active again, threw off their lethargy, and seemed well; but at the spot where the injection had been made, there was found a fluctuating tumor, gradually increasing in size, and presenting all the signs of being an ordinary abscess. When they were killed during this second stage, micrococci were more rarely found in the heart-

blood, and the infiltration of the organisms into the tissues around the abscess no longer existed, having been replaced by a firm thick wall of granulation-tissue, in which micrococci could seldom be detected, and which seemed to act as a barrier, preventing or diminishing their migration into the blood and surrounding structures. In the viscera of animals killed at this stage no organisms were detected. Some animals, however, died, overwhelmed by the blood-poisoning, at the end of the second or the beginning of the third day. In some cases the local reaction was so intense as to result, not in abscess, but in sphacelus of the site of injection and overlying skin, in which cases the animals seemed to suffer rather less from the symptoms of blood-poisoning; and, when they were killed, few micrococci were found in their blood, and the necrosed tissues were surrounded by a strong thick wall of granulation-tissue, presenting, at the places where the slough was detached, a surface like that of an ulcer covered with a thin, whitish, croupy film, in which the micrococci were growing, though in a feeble and scattered manner.

In seven cases of septicæmia in man, in which he was able to examine the blood during life by opening a small arteriole or venule, under antiseptic precautions, the blood so obtained was found to contain micrococci in every slide examined.

In a case of fatal septicæmia, death occurring on the sixth day after the extirpation of the thyroid gland, the wound teemed with micrococci. In a case of septicæmia following compound dislocation of the ankle-joint, in which death was averted by amputation, the tissues around the margin of the wound, and the subcutaneous tissue far up the leg, and the clots in and around the ankle-joint were abundantly infiltrated with micrococci. Other cases likewise, he states, that have come under his observation tell the same story. He concludes that there is no such disease as septicæmia or pyæmia *per se*, such conditions being merely secondary in the order of the morbid process, and dependent on the existence of local foci of micrococcus growth. For the focus of the disease never exists in the blood, but always in the tissues, whence the ptomaïnes generated in micrococcal proliferation pass into the circulation to act as poisons or intoxicants, though separate individuals or small groups of the micro-organisms are conveyed by the blood into other situations, so as to reproduce among other tissues the disease of the parent focus. In his summary he uses the following language: "Phlegmonous inflammation, septicæmia, pyæmia, and septico-pyæmia are all micrococcus poisoning, varied, however,

according as ptomaïne intoxication or the local tissue reaction becomes more prominent. Every feverishness, from an inflamed throat or finger, is a septicæmia in a mild degree, and may pass into a severe form. Ptomaïnes pass into the blood, and coincidently a few individuals of the micrococcus may be found to have wandered from the local disease and to be circulating in the blood, dead or half dead, owing to the unsuitability of the medium where they are, and the unfavorable influences of the forces of the tissues. If removed from the blood they rarely grow when put into suitable medium. They are all eventually extruded or consumed. But if the individual be subjected to depressing influences, the ptomaïne poisoning may not be the only phenomenon observed. As the symptoms become more severe, and the micrococci more numerous in the blood, the weakness of the individual becomes greater, and the resisting power of his tissues less, so that the micrococci are able to live in the blood, where previously they found this impossible. They multiply and form small groups that increase in size until they are too large to pass through the capillary net-work, and therefore are caught and detained in lungs, liver, or some other part. There they continue to increase during life, perhaps even for a time after death, and furnish their contribution of poison to the system. Or it may be that, though unable to multiply in the blood, they here and there throughout the body find spots suitable for their development, where they can multiply and form the foci of suppuration that mark the form for which we usually reserve the name *pyæmia*. The pyæmic secondary foci are usually in lung, or liver, or joint, but may equally well occur in lymphatic glands, secreting glands, or even in connective tissue."

In concluding the present inquiry into the relations of micro-organisms to wound-disturbances, attention should be directed to the results which have been obtained by methods of treatment that tend to prevent the access of such organisms to wounds, or to lessen their activity, if already present. By themselves alone considered these statistical clinical data would afford only presumptive evidence at best; but when taken in connection with the results of the careful, minute, guarded, experimental investigations which have occupied attention in the preceding portion of this chapter, they appear as the strongest kind of corroborative evidence of the correctness of these results. Every wound treated in accordance with the theoretical indications experimentally demonstrated becomes a check upon the correctness of the conclusions deduced from the results obtained by the experiment.

During the eighteen years which have elapsed since Joseph Lister, influenced by the results of Pasteur's investigations into the causes of putrefaction, began the use of carbolic acid as a germicide in the treatment of compound fractures in the Glasgow Infirmary, the theory that noxious germs, conveyed by the atmosphere, were the essential causes of wound-disturbances, has been tested upon a vast scale by many methods and by a multitude of independent observers.

In the Glasgow Infirmary, at the time Mr. Lister began his methods of treatment, based upon the principle of antagonizing germ-activity, infective diseases were constantly present, and became at times so prevalent that the wards had to be closed. Out of thirty-five amputations, of all kinds, done by him in two years, sixteen died, of which deaths almost all were due to infective disease—thus of the six deaths following amputations of the upper extremity, four were due to pyæmia and one to hospital gangrene. After the adoption of his new methods, though they were as yet crude, during three years, there were but two deaths from pyæmia after amputation, out of forty amputations performed, and in one of these the pyæmia existed prior to the operation. These were the only cases of pyæmia which occurred in Mr. Lister's hospital practice during these three years, though there were twenty-two compound fractures and several compound dislocations treated during this time. One case of erysipelas, and one or two cases of hospital gangrene, of a mild type, complete the list of infective diseases that occurred during this time. The results of Mr. Lister's work in the Royal Infirmary, of Edinburgh, and in King's College Hospital, of London, from 1871 to 1880, were of the same character. They will be found reported at length in Cheyne's work on antiseptic surgery, which is the source of the facts already given, and of the following statements as to results obtained by Volkmann and Nussbaum.

In 1877 Professor Volkmann, of Halle, reported that not a single case of pyæmia or septicæmia had occurred among patients treated by him aseptically during three years, notwithstanding the deaths from pyæmia and septicæmia had been so numerous previous to the adoption of this particular method of treatment that the entire closing of the hospital for a time seemed necessary.

In 1878 Professor Nussbaum, of Munich, tabulated the results of the treatment of wounds, in the General Hospital under his care, before and after the adoption of aseptic methods, thus :

Formerly.	*Now.*
"Injuries of the head, compound fractures, amputations and excisions, in fact, almost all patients in whom bones were injured were attacked by pyæmia. For example, of seventeen cases of amputation, eleven died from this cause. Even patients with severe whitlow died of it.	No pyæmia.
"Hospital gangrene had got the upper hand to such an extent, that in spite of continuous water baths, in spite of the use of chlorine water, or the actual cautery, finally eighty per cent. of all wounds and ulcers were attacked, large arteries being opened into.	No hospital gangrene.
"Almost every wound was attacked with erysipelas.	No erysipelas."

In summing up five years' experience, in the last edition of his work on antiseptic surgery, published in 1880, he goes so far as to say that "any recent wound, treated by this method is guaranteed against pyæmia, hospital gangrene, erysipelas, progressive suppuration, and in general against all accidental complications."

Schede, in the fasciculus on amputations and resections in Pitha and Billroth's "Handbuch," gives comparative tables of 321 uncomplicated amputations performed aseptically, and of 377 treated by older methods. The first were under the care of Busch, Schede, Sorin, and Volkmann. The latter were furnished by Bruns, Bardeleben, and Billroth. Of the aseptic cases 14 died, or 4.4 per cent.; of the ordinary cases 110 died, or 29.18 per cent. The causes of death were tabulated as follows:

	Septic cases.	Aseptic cases.
Pyæmia	72	0
Septicæmia	19	1
Erysipelas	2	1
Trismus	0	1
Pyæmia simplex	6	1
Hæmorrhage	3	1
Exhaustion	2	1
Shock	6	8
	110	14

William Macewen, of Glasgow, in his work on Osteotomy, published in 1880, reports 835 osteotomies of the femur, tibia, and fibula, which were compound osseous incisions or fractures treated antiseptically. In many of the patients the general health was far from being satisfactory, and was such as would have precluded most operations. The majority were in a low state of health; a number were markedly tubercular. There were many, however, who were in good general health. With the exception of eight cases, all the wounds healed by organization of blood-clot without pus-production. Of the eight which suppurated there were recognizable traumatic causes for the suppuration in seven. In one only was there no clear reason to be assigned for the pus-production. All ultimately did well, with one exception, in which case amputation was finally necessitated.

Professor H. B. Sands, of New York, in the *New York Medical Journal*, of January 6, 1883, declares that in his own experience a wonderful improvement has been wrought in the management of wounds by antiseptic surgery. Primary union is now the rule where formerly it was the exception; diffuse inflammation and suppuration are rare even after severe injuries; operations once formidable now excite little apprehension; and that dreadful scourge, pyæmia, has been nearly abolished. In the surgical service of the Roosevelt Hospital, containing seventy-five beds, no operation performed during the last three years has been followed by septicæmia or pyæmia.

Professor William Stokes, of Ireland, in the "Address in Surgery," before the British Medical Association in 1882, claims that one of the best tests, if not the best, for the value of antiseptic practice, is resection of the knee-joint, as there are so many circumstances that militate against immediate union being obtained after it. In the first place, as he says, the cases requiring so formidable an operation, are, as a rule, in a condition of great physical exhaustion, consequent on long confinement, and probably protracted suffering of mind and body. The wound is of necessity a large one; the operation occupies a considerable time; two large freshly cut bone surfaces are made, between which union is to take place; and, lastly, there is the great difficulty of keeping, no matter what appliance be adopted, the limb absolutely at rest during the process of union. Before the adoption of Listerism the surgeon anticipated that four, six, or eight months, or longer, would elapse before union took place, and it was always a subject discussed at consultations on these cases, previously to operation,

whether the patient would have strength to endure so protracted a suppuration. As an illustration of how changed matters are now, he quotes a series of fourteen cases of excision of the knee-joint, in nine of which the wounds united without a trace of pus-production; and in another, the last of the series, only two dressings were required subsequent to the one applied at the time of the operation, and in seven weeks after the patient was up and going about. He further states that in a record of upward of six hundred operations performed by himself and his colleagues at the Richmond Surgical Hospital during the previous three years, an institution which was hygienically in a very unsatisfactory condition, the mortality was 3.6 per cent.; there was not a single case in which the methods of Lister were accurately employed that was followed by any infective disease.

With regard to the course of repair in the wound-site itself, Cheyne testifies that where wounds have been treated in accordance with the aseptic methods of Mr. Lister no inflammation occurs; there is no swelling nor redness of the edges, as is so frequently the case in wounds treated otherwise. The skin around the wound remains as pale and lax as it was when stitched up at the time of the operation; there is no evidence of reaction; inflammation is absent from the deeper as well as from the superficial parts of the wound. There is no suppuration even when the deeper structures are not absolutely in contact. The discharge from the drainage-tube is purely serous, and rapidly diminishes in amount so as to render the drain unnecessary in a very short time. Wounds heal, as a rule, much more rapidly than when treated otherwise; as a result of the absence of inflammation in the deeper parts, the scar does not become adherent but remains movable.

Of the same character is the testimony of Professor James L. Little, of New York, in remarks made by him before the New York Surgical Society, November 8, 1881, in which he said that during a period of six years he had treated nearly three hundred cases of open wounds, these injuries consisting chiefly of wounds of the hands and fingers caused by their being caught in the cogwheels and other parts of machinery. In many cases fingers were torn off, tendons pulled from their sheaths, joints opened, and hands often severely crushed and lacerated. Many of these patients were in an unhealthy condition, some suffering from anæmia, some from cardiac disease, phthisis, and the like. Under antiseptic dressings, not one of these wounds was followed by inflammatory symptoms.

Extensive lacerated wounds healed, and dead tissue sloughed away without giving rise to any of the so-called symptoms of inflammation. Neither pain, redness, heat, swelling, nor constitutional disturbance resulted. In no case was there reddening of the lymphatics or tenderness of the glands. No counter-openings were necessary. Pain was entirely absent, so that anodynes were not needed, save in a single case, and that for one night only, to control slight restlessness.

Citations of a similar character to the preceding could be made from the testimonies of an indefinite number of surgeons on both sides of the Atlantic. They are alike in their statements that, in proportion as it has been possible for them to perfect methods of wound treatment by which the development of micro-organisms could be prevented or diminished, disturbances of repair have been escaped and healing has been safe and speedy and perfect.

In bringing this chapter to a close, there confronts us the question, What conclusion as to the relation of micro-organisms to wound-disturbances is most consistent with all the facts which have thus far been established? Three great groups of phenomena present themselves from which to draw pertinent observations, viz.: 1, the behavior of wounds which were exposed to the access of micro-organisms or their germs, and which presented conditions favorable for their vital activity; 2, experimental research as to the nature and the effects produced by the different species of micro-organisms; and, 3, the effects upon the course of healing in wounds produced by protecting them from germ invasion or by destroying or diminishing the activity of such as may have gained access to them.

In the first class are all open wounds, in which the conditions favorable for the development of activity of germs sown upon them become the more pronounced in proportion as the amount of devitalized tissue, and of blood-clot, and the number and depth of recesses for the reception and retention of wound-secretions increase.

Observation of this class records that invariably their repair is disturbed by putrefaction and sloughing of the devitalized tissues, by decomposition and liquefaction of the blood-clots, by inflammation of the wound-margins, and by a prolonged process of suppuration and granulation, and, in a certain number of cases, by grave septicæmia, and by pyæmia.

In the second class stand out the facts that no decomposition or fermentation takes place in organic matter without the agency of some form of micro-organism; that when no decomposition of wound-tissues or

secretions takes place no wound-disturbance occurs; that certain forms of micro-organisms are always found associated with certain forms of wound-disturbance; and finally, that these micro-organisms, when isolated and introduced anew in sufficient amount among tissues previously healthy, are capable of exciting here the same diseased action with which they were originally found associated.

In the third class are subcutaneous wounds, in which the unbroken skin forms a perfect shield against the invasion of noxious organisms from without; wounds involving the integument, in which apposition of the divided surfaces can be secured and maintained, and the retention of wound-secretions prevented, and in which the inherent force of the constructive power of the healing tissues is great enough to destroy whatever germs may gain access while the surfaces are exposed; and wounds of every class in the treatment of which adequate measures have been used to prevent the access of germs, or to destroy them, or prevent their development if present.

Clinical observation records, for all the members of this third class in which protection from invasion of micro-organisms is secured in various ways, a common immunity from wound-disturbances. The repair of subcutaneous wounds is, as a rule, free from suppuration, inflammation, and sloughing, or other serious complication, even though involving much contusion and laceration of soft parts and extensive effusion of blood. Union by first intention, without disturbance, accident, or delay, is the rule when the conditions next mentioned are obtained; and, in like manner, a course of repair free from disturbance and closely approximating in rapidity and perfection that of subcutaneous wounds is enjoyed by the last-mentioned wounds. The evidence which each of these groups of phenomena gives is harmonious and cumulative, and the only conclusion which is consistent with them is that the local suppurative and inflammatory, and the general infective disturbances which occur in wounds result from the vital activity of micro-organisms, which having been introduced from without, find in the wound the conditions that favor their development and increase.

Other sources of irritation likewise exist and are capable of exciting suppuration and inflammation in wounds, but their effects are limited and transient in character, their action is easily recognizable and preventible, and their chief importance springs from the manner in which the conditions created by them favor the activity of micro-organisms.

CHAPTER IV.

ASEPSIS AND ANTISEPSIS—WOUND-CLEANLINESS.

The Scientific Basis of Wound-Treatment—Ptomaïnes—Sepsis—*Asepsis*—*Antisepsis*—*Cleanliness*—Primary Cleansing of a Wound—Drainage—Cleanliness of Adjacent Tissues—Cleanliness of Wound-Dressings—Air Purification—Antiseptic Sprays—Practice of Lister—Experiments of Stimson and Duncan—Effects of Sprays.

THE recognition of the activity of micro-organisms as the essential cause of disturbances of repair in wounds supplies a scientific basis for treatment and affords a definite principle by which to test methods of wound-treatment. It has been seen that it is not the organisms themselves that are the irritants that directly cause wound-disturbance, but the products that are formed in the course of their growth and multiplication, either directly secreted by themselves or formed by the decomposition of the substances on which they feed. These secondary products—ptomaïnes—are poisons or septic agents, and the results in general of their action upon the living tissues with which they come in contact constitute *sepsis*. Whatever tissue or wound-surface is uncontaminated by these ptomaïnes is in an *aseptic* condition, and whatever method or means antagonizes their production, or antidotes, restricts, or removes the results of their presence is an *antiseptic*.

The ideal treatment of a wound is that by which a perfectly aseptic condition should be obtained and preserved; where this is impracticable, the object of treatment becomes changed to the application of means to diminish the activity of the septic organisms, to secure the rapid removal of their products, and to increase the resisting power of the wounded tissues.

ASEPSIS.

Asepsis is present in wounds which are subcutaneous, and in wounds which unite by first intention. The defects of apposition, protection, or nutrition which may prevent the accomplishment of union by first inten-

tion in a wound do not necessarily expose it to septic infection, but so much do they increase the difficulties of preserving the wound from such infection that the means of remedying these defects, and of securing union by first intention, when the conditions of the wound make it at all possible, become of the highest importance from the standpoint of the dangers of sepsis. The methods by which these defects are to be avoided belong to the practice of wound-treatment and will be reserved for consideration in that connection. Attention here must be restricted to general considerations bearing directly upon the prevention or correction of sepsis.

Asepsis may be preserved, if the wound is to be inflicted by the surgeon himself, by care in permitting access to the wound, at the time of its infliction and during its after progress, of no object which is contaminated by septic agents. This involves purification of the air, instruments, dressings, and of the hands of the surgeon himself, and the most minute, exact, and persistent care throughout the course of the wound until its final cicatrization.

In wounds already septic, asepsis may be obtained by applying to their surfaces and recesses substances capable of destroying the septic germs and organisms present, and by using in their after-care dressings capable of excluding the further access of septic agents, or of preventing their development if their exclusion has been impossible.

ANTISEPSIS.

In wounds in which, for any reason—their location, their complications, the absence of necessary appliances, or whatever other cause—asepsis is impossible or impracticable, the effects of the septic agents that may be present may be modified and restrained, not only by the application to the wounds, as thoroughly as possible, of antiseptic substances, but also by the most perfect removal from the wound of devitalized substances and those prone to decomposition, which if left would be rich feeding-ground for micro-organisms, by the immediate removal of the noxious products of the septic condition as fast as produced, and by whatever agencies are capable of promoting general reparative energy or local resisting power in the wound-tissues.

The range covered by this enumeration of the means and methods of antagonizing septic conditions in wounds—antisepsis—is a wide one, and

includes every form of wound-treatment which by experience has been found to favorably affect the healing of wounds. Those methods only, however, which in a special manner modify the vital activity of noxious micro-organisms, or nullify the results of such activity, can be considered in this connection. These methods will be considered in the following order:

First.—Those that are required to prevent the accumulation, or to ensure the removal of whatever substances might afford a pabulum favorable to the growth and increase of septic organisms; to facilitate the removal of septic products, if formed; and to prevent the introduction into the wound of any substance capable of inducing septic changes in it; these methods are embraced in the single idea, *cleanliness*.

Second.—The employment of substances as applications to wound-surfaces which are inimical to septic organisms, destroying them or restraining their growth—*antiseptics*, in the more restricted sense of the term.

CLEANLINESS.

That aspect of cleanliness which has to do with the prevention of the accumulation, and with the speedy removal of fermentable substances from a wound requires for its accomplishment, at the beginning of treatment, the removal of every substance which either itself should foster the growth of micro-organisms, or should provoke undue secretion from the wound, or that by the mechanical effect of its presence should delay union. The accomplishment of this end constitutes *primary cleansing of the wound*. The full performance of this cleansing may, however, involve such increased hazards from the additional traumatism required for its accomplishment in some instances, that it may best be ignored, as in cases of bullets, needles, and other bodies that have penetrated the tissues, and, becoming encysted, cease to irritate, and disturb but little the function of the parts in which they rest. Again, in cases in which an accumulated blood-clot would appear to violate the rule of cleanliness by its proneness to decomposition and by the mechanical effects of its presence, if it can be kept aseptic, or if efficient means of antisepsis be available, it may, in cases of open wounds, with loss of substance so great as to prevent apposition of the divided surfaces, really facilitate repair by affording pabulum, support, and protection to the forming granulation-tissue that gradually takes its place. In cases, also, in which rapid drying of a layer of blood-clot

can be accomplished, the impermeable layer which it forms may constitute a perfect occlusive antiseptic dressing for the wound underneath it; but the doing up of a wound "in its own blood," to be successful, requires that the other possible demands of cleanliness that may be present or may arise in the wound be also regarded.

Of equal importance with the primary cleansing of the wound is the prevention of the accumulation within its cavity at any time in its after-history of wound-secretions and tissue-débris. The abundant serous exudation which occurs as the immediate result of the active hyperæmia provoked by a wound, bathes in abundance the free surfaces of an open wound and gathers in its recesses, and when such wounds are closed externally, if exact apposition of its deeper parts be not also secured and maintained, separates its surfaces, and as long as it is retained, not only disturbs repair by the tension produced, but also offers the best of pabulum for promoting the vital activity of ferment-producing organisms. The prevention of such accumulation and retention becomes, therefore, of the highest importance in attempts to preserve a wound from disturbance.

Again, when suppuration has occurred in a wound, the pus brings into the wound the same elements of danger which attend the earlier serous exudation, with the added condition that septic products are already being mingled with the wound-secretions.

The spontaneous escape and draining away of all secretions and tissue-débris, as fast as exuded or separated, may be provided for either by the special arrangement of the wound-surfaces alone, or by the use of apparatus to drain them away. This portion of the requirements for securing cleanliness in wounds is termed *drainage*.

To so manage a wound as to prevent or to restrain the primary serous effusion will diminish the necessity for provisions for drainage. This can be accomplished in great measure in all wounds in which such apposition of the surfaces can be secured as to make union by first intention possible. This should be the ideal to be striven for in all such cases. Its accomplishment means careful and perfect hæmostasis, careful primary cleansing, careful expression from the wound-cavities as its surfaces are being brought into apposition of all fluids present, perfect coaptation throughout all parts of the wound, deep and superficial, gentle compression, and support and perfect protection, with infrequent dressings thereafter. With the perfect accomplishment of such precautions no accumulation of serum is possible, and provisions for drainage are unnecessary and objectionable.

But whenever accurate coaptation is not secured, and a cavity exists in which fluid may accumulate, its drainage must be provided for.

The last requirement of wound-cleanliness, according to our analysis, is the prevention of access to the wound of any substance capable of inducing septic changes in it. From their relation to this requirement must be considered: 1, *Cleanliness of adjacent tissues;* 2, *cleanliness of wound-dressings;* and 3, *cleanliness of the air* that comes in contact with the wound.

Adjacent Tissues.—Perfect cleanliness requires not only that the tissues immediately adjacent to a wound be purified of gross impurities, but that they should especially be freed from any micro-organisms which might, by gaining access to the wound, make it septic.

Examination of the skin on regions much subjected to frictions and ablutions, as the hands, fronts of the thighs, arms, and forearms, shows micro-organisms so sparingly that epidermis removed from thence by scraping may often exhibit few or none. But in individuals who, from any cause, do not practise frequent ablutions, even in these regions they are usually found, while in not even the most cleanly person does the interdigital scurf of the toes fail to show abundance of both micrococci and bacteria. The scurf of the scalp contains mostly fungi and fungus spores, and is by no means rich in cocci or bacteria, while the secretion of the umbilicus shows both these forms to be present in abundance.

Micrococci are numerous in the cerumen of the ears and in the mucus on the lips, and there exceed in number the other forms of organisms. In the axilla, on the other hand, where micro-organisms are in great plenty, the bacteria preponderate, and in the secretion from the skin of the nose, that is mostly sebaceous, obtained by gently compressing its tip, almost the only forms met with are the bacteria, which are there, however, innumerable.

Sebum expressed from scrotal or perineal follicles shows multitudinous bacteria, slender rods, and micrococci; the anal region shows thick and slender bacilli, bacteria, and micrococci; while the fæces and interior of the bowels present the appearance of being entirely composed of infinite colonies of all varieties.

The author[1] on whose authority these statements are made adds:

"We need not even call into account the solids, fluids, and gases around us in our search for sources of infection when we possess in our

[1] Dr. Alex. Ogston: Micrococcus Poisoning. Journal of Anatomy and Physiology, Vol. XVI., p. 557.

own frames so abundant a supply. In relation to surgical questions, it is of use to know the extent and distribution of these germs on our persons, if our processes of disinfection are to be conducted aright. In operative procedures on the axilla and scrotum, for example, we ought to know that all our preliminary washings and disinfection are impotent to exterminate the micro-organisms that exist in the openings of the glands to a depth of one-fourth of an inch and even more. None of the proceedings in use in antiseptic surgery is of any avail to destroy them; they will continue to grow and reach the surface, and unless we maintain there a storehouse of some disinfectant material, frequently renewed, that will suffice to saturate all discharges and convert them into aseptic fluids, we shall assuredly find the organisms growing richly under our dressings. Iodoform and salicylic acid, which are treasure-houses of disinfection, are more useful in those regions than on the arms, legs, and hands. But even in these purer territories over-confidence is perilous, and where we are dealing with skins not regularly cleaned, as is the case, for instance, to a large extent in hospital practice, we have to add to our habitual precautions, and attend both to preliminary saturation of the epidermis with penetrating disinfectants and to the subsequent maintenance of stores of disinfectants on the surfaces where the germs may develop and appear. For a considerable time back I have found it advantageous, in any operation that involved serious danger, and that required to be successful at all hazards (operations of complaisance, such as osteotomies and joint operations), to dress the part for days before operation in a regular Lister's dressing, renewing it daily, and saturating the skin with carbolic water, besides washing the part with turpentine immediately before making the first incision. I do not think I am wrong in saying that we are too easily satisfied with our cutaneous disinfection, and that the chief source of micro-organisms in wounds is from the skin, rather than from the air or failures in our antiseptic procedures."

The difficulty of securing the desired purification of the adjacent tissues becomes almost insuperable in wounds involving the mucous orifices of the body, so that unless they are of such a character that perfect apposition of the wound surfaces can be secured, and immediate union by first intention obtained, they inevitably become septic wounds. Such wounds, therefore, cannot be treated by occlusive methods; efforts must be directed to antagonizing the inevitable sepsis and removing its products. But in all wounds, whether operative wounds at the hands of the surgeon or

wounds accidentally inflicted, in which attempts at rendering and keeping them aseptic offer any hopes of success, all such attempts must include the purification of that portion of the skin which is covered in by the dressings, as much as the wound-surfaces themselves. Too great care in cleansing it cannot be taken.

Wound-Dressings.—In this class are to be included everything which necessarily is brought in contact with the wound in the attentions which it requires, as well as those substances which are applied more or less permanently to the wound to promote its healing. The persons of the surgeon and his assistants, the instruments and appliances of every kind that are used in or about the wound, the fluids that are used for irrigation, the drains, the ligatures, the sutures, the compresses, and protective appliances, must each equally comply with that degree of cleanliness which shall be necessary to prevent them from becoming the bearers of infection.

AIR PURIFICATION.

The more obvious sources of atmospheric impurity are overcrowding, deficient ventilation, the presence of unhealthy suppurating wounds, the presence of infectious diseases, the proximity of walls, beds, or other absorbent materials charged with septic emanations, the vicinity of cesspools, sewer-basins, masses of putrefying material, or other foci of infection. The mention of these is sufficient to suggest the means of remedying them. No one of them should be overlooked in considering the cares to be rendered a wound. To the results which attend their neglect, attention has been called in a previous chapter.

The air of the country is more free from micro-organisms than is the air of a city, and that of the upper floor of a house than that of the lower floor. Facts that should be borne in mind when a choice as to where a wounded person should be treated is possible. After every ordinary precaution possible has been taken to secure a pure atmosphere by clean and pure surroundings, isolation, and abundant ventilation, what further means are necessary and available for securing absolute air-purity?

As has been stated in a previous chapter, putrescence invariably follows a sufficient exposure of putrescible fluid to the air, the length of the exposure needed being dependent upon the character of the local surroundings. Dr. Duncan, of Edinburgh,[1] found that in his laboratory a

[1] Germs and the Spray. Edinburgh Medical Journal, March, 1883, p. 778.

fluid presenting a surface of an inch and a quarter, could be repeatedly exposed for nearly two hours without infection, and that to be reasonably certain of putrescence a surface of three inches and a quarter required an exposure of twenty minutes. The volumes of air that may be free from infective germs may be considerable in favorable localities, but, as there is no uniformity in the distribution of floating organisms, no given volume can be relied upon as absolutely pure.

Antiseptic Sprays.—With the view of procuring absolute purity, at will, of all air coming in contact with a wound, Mr. Lister has recommended to fill the atmosphere about a wound, as long as it is exposed, with a spray of a carbolic acid solution, believing that the acid has the property of killing whatever germs might be floating in the air thus charged. Of this use of a spray, however, Mr. Cheyne, in his "Antiseptic Surgery," says (p. 73): "Of all the precautions required by Mr. Lister, that of purifying the air by means of a carbolic acid spray is the least necessary, for there are but few septic particles present in the atmosphere, and even though some of them fall on to a wound, they may be rendered inert by washing the wound with carbolic lotion. . . . If at the present time he were compelled for any reason to give up some one precaution, he would at once throw aside the spray, as that one which is least necessary, and which could be the most readily dispensed with."

The results of observations made by others have not confirmed the supposed power of the carbolic acid spray to kill floating germs. Experiments made by Stimson,[1] of New York, in 1879, demonstrated that particles of atmospheric dust, after having passed through a cloud of carbolic spray, are still capable of exciting putrefaction in liquids upon which they lodge. Duncan, of Edinburgh, in his article on "Germs and the Spray," already referred to, reports the results of extended and repeated experiments, which definitely prove that, so far as the destruction of floating germs in the air is concerned, the spray is perfectly ineffectual. "When we consider the researches published by the German Health Bureau, it seems somewhat doubtful whether the carbolic acid spray ever killed a single healthy bacterium; the vitality of certain spores is certainly not thereby affected" (Belfield[2]). Instead of being beneficial, it is possible that a spray directed upon an open wound may be positively harmful

[1] An Experimental Inquiry into the Value of the Carbolic Spray as a Preventive of Putrefaction. Amer. Journ. Med. Sciences, January, 1880.

[2] Sepsis and Antiseptic Surgery. The Medical Record, March 3, 1883, p. 231.

by reason of the air-currents which it produces, for, as Duncan observes, if the spray is made to play across a beam of sunlight, the floating dust may be seen in clouds rushing toward and being whirled along with it, so that one can hardly doubt that the margin of the spray is the most dangerous position in which a wound can be placed, and that a slight deflection from a current of air may result in the entrance of this floating matter to recesses where the solution deposited by the spray may never reach.

The observations of Miquel, at the Montsouris Observatory (see page 39), of the purification of the atmosphere from floating organisms produced by rain-storms, indicates how the spray may be made a valuable agent in promoting the purity of the air in any given space. By means of the spray-producer it is possible to have a local rain-storm, at any time by means of which the floating matter in the air may be mechanically precipitated. The temporary comparative purification thus secured would not be increased by the addition of a small proportion of any antiseptic substance to the material used for the spray, although such addition would not be objectionable. As the spray washes down upon the surfaces upon which it falls the floating matter which it carries with it, it should not be used so as to fall upon a wound. In the case of a surgical operation, or of the dressing of a wound, its use should be preliminary to the exposure of the wound.

In most wounds, whatever germs may be deposited on their surfaces from the atmosphere may be readily destroyed by irrigation with antiseptic liquids, but in some the deep and irregular recesses which characterize them, or the extent of the natural cavities into which they open, as in wounds of the great serous and joint sacs, make perfect irrigation uncertain. In dealing with such wounds the additional precaution of washing the air of the room by means of a preliminary spraying promises advantage.

CHAPTER V.

WOUND-DISINFECTION—ANTISEPTICS.

Antiseptics in General:—Comparative Germicidal Strength of Various Agents—Strengths Required to Restrain Germ-Development—Local Effect of Antiseptics on Tissues—General Toxic Effects. *Special Antiseptics*:—Corrosive Sublimate—Permanganate of Potassa—Carbolic Acid—Its Advantages—Its Disadvantages—Carbolic Intoxication—Chloride of Zinc—Salicylic Acid—Boracic Acid—Acetate and Aceto-Tartrate of Alumina—Iodine and Iodoform—Iodoform Intoxication—Naphthalin—Subnitrate of Bismuth.

In addition to the resources of cleanliness for preserving wounds from becoming the seat of the vital activity of micro-organisms, there still remains to the surgeon the employment of direct applications to the wound-surfaces of substances which have the power either to destroy them outright or to restrain their growth. In general parlance the application of the term *antiseptics* is restricted to these substances.

The possibility of obtaining antiseptic results in a wound by agents that simply restrain the growth of septic organisms, as well as by those that destroy them, is a matter of great practical importance, for it has increased the number of substances available for antisepsis, and since the preventive effects of many agents can be accomplished by much smaller amounts than their destructive effects, it has been found possible to obtain their antiseptic effects with less local irritation of the wound itself and less liability of danger from absorption of poisonous quantities of the agent into the blood.[1]

---

[1] This inhibitory action of certain agents is similar to the effect upon certain processes of vegetable life exhibited by anæsthetics. "The addition of ether to an infusion containing yeast, at once arrests the process of fermentation. On removal of the anæsthetic, by evaporation or by filtration, the activity of the yeast fungus is renewed, and fermentation is again resumed. If an aquatic plant be placed in a watery solution of ether or chloroform, its absorption of carbonic anhydride and its exhala-

In estimating the usefulness of any agent as an antiseptic application in the treatment of wounds, three things have to be taken into consideration.

1. Its power as a germicide or germ-restrainer.

2. Its immediate local effect on the wound surfaces—neutral, irritant, or caustic.

3. Its remote constitutional effect when absorbed into the general circulation.

Some general considerations under each of these should receive attention before taking up individual antiseptics.

1. *What amounts of the various antiseptic agents are necessary to introduce into a wound, to secure the destruction or resist the multiplication of whatever septic germs may have gained access to it?*

The fact that germs of different species manifest different degrees of vital resistance to chemical reagents, and that differences in the physical condition of the same species of germs at different times likewise cause variations in the effects produced by applications made to them, must always be borne in mind in the clinical application of experimental researches as affecting the precise strength of an agent needed to antagonize possible septic germs.

The experiments of Dr. George M. Sternberg[1] give the following amounts as the strengths required for certain reagents, enumerated, to destroy the vitality, or to prevent the development of the micrococcus of pus. The fluid containing the micro-organisms, with proper precautions to guard against errors, was subjected by this experimenter to the test liquids for a space of two hours. The following table exhibits the strengths needed to destroy the organisms :

---

tion of oxygen cease. The plant does not die ; it merely sleeps. On replacing it in pure water, its natural respiration is immediately resumed. The germination of seeds may also in a similar manner be arrested by surrounding them with an anæsthetic atmosphere" (Lyman : Anæsthetics and Anæsthesia ; The International Encyclopædia of Surgery, Vol. I., p. 409).

[1] Experiments to determine the Germicide Value of certain Therapeutic Agents. American Journal of the Medical Sciences, April, 1883, p. 335.

TABLE OF GERMICIDAL STRENGTHS.

Reagent.	Efficient in the proportion of one part in
Mercuric bichloride	20,000
Potassium permanganate	833
Iodine	500
Creosote	200
Sulphuric acid	200
Carbolic acid	100
Hydrochloric acid	100
Zinc chloride	50
Tinctura ferri chloridi	25
Salicylic acid dissolved by sodium borate	25
Citric acid	8
Chloral hydrate	5

The following-named reagents failed in the proportions given below, which were as far as the experiments were conducted with them :

	Failed in the proportion of
Fowler's solution (arsenite of potassa)	40 per cent.
Sodium hyposulphite	32 "
Sodium sulphite (exsiccated)	10 "
Ferric sulphate (saturated solution)	16 "
Potassium iodide	8 "
Liquor zinci chloridi	8 "
Zinc sulphate	20 "
Boracic acid (saturated solution)	4 "
Sodium borate (saturated solution)	4 "
Sodium salicylate	4 "

Similar experiments made with the micrococcus of gonorrhœa, the micrococcus of septicæmia in the rabbit, the bacterium termo, and upon the organisms developing in broken-down beef-tea which had been freely exposed to the air, showed that in general those reagents which destroyed the vitality of the micrococcus from pus are equally efficient when a different micro-organism is used. The most uniform power was displayed in all the cases by mercuric bichloride and by iodine, which the author presents as germicide agents of the highest value, giving as the proportion in

which they would certainly be efficient as one part in five thousand for mercuric bichloride, and one part in two hundred for iodine.

Experiments made to determine the minimum quantity of the reagents named required to prevent the development of the various micro-organisms gave results which also were found to be pretty uniform for the three different organisms. As will be seen in the subjoined table, boracic acid, sodium biborate, and salicylic acid dissolved by means of sodium biborate, though they had not been found to possess any germicide value, even in four per cent. solutions, proved to be potent in preventing the development of septic organisms. This power is more marked in the case of the bacterium termo, a putrefactive organism, than in that of the micrococcus of pus.

The following table shows the minimum quantity required to prevent the development of the micrococcus of pus.

TABLE OF STRENGTHS REQUIRED TO RESTRAIN GERM-DEVELOPMENT.

Reagent.	Efficient in the proportion of one part to
Mercuric bichloride	35,000
Iodine	4,000
Sulphuric acid	1,800
Carbolic acid	500
Salicylic acid and sodium biborate, equal parts	200
Boracic acid	200
Ferric sulphate	200
Sodium biborate	100
Alcohol	10

Comparison of the two tables shows that the more potent germicides have the power of restricting multiplication in quantities considerably less than are required to destroy vitality.[1] In the case of iodine, the difference

[1] The following table of results obtained by Koch in the laboratory of the Imperial Board of Health at Berlin (*Mittheilungen aus dem kaiserlichen Gesundheitsamte*, p. 236, Berlin, 1881) may be compared with the results of Sternberg:

Strength of reagent.	Time of exposure.	Effect.
Corrosive sublimate, aqueous solution, 1 to 100.	1 day.	Total destruction of life.
Permanganate of potash, 1 to 20	"	"
Permanganate of potash, 1 to 100	2 days.	No effect.

is eightfold; in that of carbolic acid, fivefold; in that of sulphuric acid, fourfold, etc.

The substances included in this list tested by Sternberg include the most of the more common reagents that have heretofore been in use in solution, as antiseptic lotions, in the treatment of wounds. The results of these experiments are of great value in giving a standard by which to judge the merits, as antiseptics, of various agents, and also by which to determine the strength of the antiseptic solution to be used in any given instance; though prudence may require that solutions of considerably greater strength than the minimum quantities, determined as sufficient for antiseptics in the flasks used for these laboratory experiments, be used for the disinfection of actual wounds.

In addition to these soluble agents, a new class of agents, insoluble, powerless, or comparatively insoluble, has recently been added to the list of antiseptics. These now include iodoform, naphthalin, and the subnitrate of bismuth. They remain to be subjected to a similar series of tests to determine the minimum strengths in which they must be present to exert certainly an inhibitory effect upon germ-growth.

2. *The effect which a substance introduced into a wound as an antiseptic may have on the exposed surfaces of the wound must be taken into consider-*

Strength of reagent.	Time of exposure.	Effect.
Osmic acid, 1 to 100	1 day.	Total destruction of life.
Turpentine, oil of	5 days.	"
Chlorine water, freshly made	1 day.	"
Bromine, 1 to 50	"	"
Iodine water	"	"
Iodine, alcoholic solution, 1 to 100	——	Hindered growth only.
Chloride of lime	5 days.	Total destruction of life.
Chloride of iron	6 days.	"
Arsenic, 1 to 100	10 days.	"
Sulphurous acid water	——	Very slightly efficacious.
Sulphuric acid, 1 to 100	10 days.	Hindered growth.
Boracic acid, 1 to 20	6 days.	"
Borax, 1 to 20	15 days.	No effect.
Quinine, 1 to 100	10 days.	Total destruction of life.

Carbolic acid, aqueous solution, from 1 to 100 to 1 to 20, is sufficient to destroy organisms that have not passed into the spore condition. For the sure destruction of the spores of the anthrax bacilli a strength of 1 to 10 is necessary.

ation in choosing one for use, as well as its effect upon the germ supposed to be present.

A pronounced irritating or caustic effect may render an agent unfit for use upon living tissues. Even if but slightly irritating, the increased serous flow, which its application may provoke, will seriously embarrass the attempt to prevent the development of septic conditions in it. The property of producing upon wound-surfaces a thin film of coagulated albumen uncongenial to the growth of germs, as a protection of the surfaces covered by it, and which, by pressure, tends to restrain effusion, has extended greatly the usefulness of so feeble an antiseptic as chloride of zinc; the freedom from irritation of iodoform and bismuth powder, and their properties of absorbing moisture and exercising compression upon the surfaces to which they are applied, thus restraining secretion, add greatly to their antiseptic powers.

3. *The possibility of the production of general toxic symptoms by absorption of the agents used as local antiseptic applications is always to be borne in mind as a consideration checking the unlimited use of these agents.*

The amount of danger attending the use of particular agents will be considered in connection with each. In general, however, it may be stated that the larger the surface exposed to the action of the agent, and the more prolonged the exposure, the greater the danger of absorption in toxic quantities becomes.

The special properties of individual antiseptics will now be considered, including, however, only such as have been found by experience to be of value as wound applications. They will be taken up in the following order: *Corrosive Sublimate, Permanganate of Potassa, Carbolic Acid, Chloride of Zinc, Salicylic Acid, Boracic Acid, Acetate of Alumina, Iodine and Iodoform, Naphthalin, Subnitrate of Bismuth.*

CORROSIVE SUBLIMATE.

Though the efficient anti-putrefactive properties of the mercuric bichloride, or corrosive sublimate, had been known for a long time, its employment in the treatment of wounds had been prevented by fears of its toxic effect through absorption, and also by the ardent advocacy of the sufficient merits of other agents.

The publication of the researches of Koch upon the bacilli of anthrax, the spores of which, though they were unaffected by other antiseptics, were

killed in a few minutes in a solution of corrosive sublimate, 1 to 1,000, and were prevented from developing by a solution of 1 to 5,000, has inspired surgeons to trials of this agent, the results of which have been very satisfactory. In the Hamburg General Hospital, during seven months beginning with November, 1881, Schede and Kümmell used no other antiseptic, except for the spray and for the bath for instruments, for which purposes carbolic acid, 1 to 20, was used. These surgeons employed solutions varying in strength from 1 to 100 to 1 to 5,000. Although large quantities of the stronger solution were used, and the cases were closely watched for constitutional toxic symptoms, in only two cases out of over two hundred did any salivation occur.[1]

These surgeons report that the healing of the wounds, in the dressing of which the sublimate is used, is accomplished with a certainty and uniformity unknown under any other dressing. Esmarch and Neuber, of Kiel, have recommended it strongly as an adjuvant to the peat dressing. Out of 212 cases of extensive wounds treated by them with the sublimate and peat dressing, in only 11 cases was the dressing changed more than once. No toxic symptoms were observed in any of these cases.

Weir, in the New York Hospital, has used it with satisfactory results.[2]

The sublimate solution is free from odor, and does not irritate the wound. By its use the wound-secretions markedly decrease, and wounds previously offensive become speedily sweet. In some instances it produces a roughness of the skin, and in an easily irritated skin an eczema may also be provoked. For purposes of irrigation a solution of 1 to 1,000 (about 8 grains to the pint of water) will afford a standard solution of reliable antiseptic strength. A solution of the same strength should be used for immersing the sponges and compresses, and also for the permanent preservation of the silk used for sutures, after they have first been soaked for two hours in a solution of 1 to 100 (76 grains to the pint). Any external dressings applied may be impregnated with the sublimate, as previously described. For the disinfection of instruments it cannot be employed on account of its corrosive action on the metal of which they are made.

---

[1] H. Kümmell: *Ueber eine neue Verbandmethode*, etc. *Archiv für Klinische Chirurgie*, *Band* xxviii., *Heft* 3.

[2] The Weak Points in a Lister Dressing, and the Advantages of Corrosive Sublimate as an Antiseptic. New York Medical Journal, May 19, 1883, p. 549.

PERMANGANATE OF POTASSA.

Since permanganate of potassa was brought to the notice of the profession by Mr. Condy, in 1857, its antiseptic powers have been recognized, and it has been much used for purposes of irrigation, in aqueous solutions of from 5 to 20 parts to 100. The rapidity with which it becomes decomposed when brought into contact with organic substances unfits it for use as an agent to secure prolonged antiseptic effects.

CARBOLIC ACID.

The use of carbolic acid as an antiseptic owes its introduction to Lemaire, of France, who published a work entitled "De l'acide phénique" in 1863. Lemaire was the first to use carbolic acid, and was the first to realize the truth of the germ theory as applied to wounds.[1] The first interest in the use of this agent had in great degree subsided, inasmuch as the use of it, applied in the way recommended by Lemaire, had failed to give satisfactory results, when it was taken up by Mr. Lister, in 1866, in his wards in the Royal Infirmary of Glasgow, and by him brought through various modifications of use until a complete system of wound-dressing, based upon its antiseptic properties, known as the Listerian method, was ultimately elaborated.

This agent still remains the one in more general use as an antiseptic than any other, chiefly through the impetus received by the marked and certain immunity from septic accidents in wounds which surgeons were, for the first time, able to secure by its use according to the methods prescribed by Mr. Lister. Whether a more accurate knowledge of the character of the agencies which are capable of disturbing the repair of wounds, and the power of other agents to equally or more certainly counteract them, shall cause carbolic acid to become measurably obsolete in the future or not, to carbolic acid itself will always attach the interest which comes from having been the agent through which the possibilities of antiseptics in the treatment of wounds were first demonstrated; and whether in future the technique of Mr. Lister in the dressing of wounds, when antisepsis is desired, shall continue to be adopted or not, to him will ever remain the credit of having first appreciated the full relations of sepsis to wound-disturbances, and of having devised a method by

[1] Cheyne: Antiseptic Surgery, p. 356.

which septic infection in a wound was certainly guarded against, and of having inaugurated a new era in wound-treatment in which it was elevated from the position of an empirical art to that of an exact science.

Carbolic acid is a product of the destructive distillation of coal. Pure carbolic acid is absolute phenol, C_6H_6O. It is supplied as a pinkish crystalline mass, readily soluble in fifteen parts of water at the ordinary temperature. When subjected to slight heat it liquefies, and may be made permanently liquid by adding to it five per cent. of water.

The ordinary commercial acid contains an homologous substance, cresol, which does not crystallize, and, though very deliquescent, does not dissolve readily in water. It has equal antiseptic properties, but is more irritating and causes numbness and tingling of the skin in a much greater degree than the pure acid does. One part of the ordinary commercial acid will dissolve with some difficulty in twenty parts of water.

Carbolic acid is freely soluble in glycerine and in alcohol, and readily blends with oil in any proportion. The following practical remarks as to its preparations and their uses are mainly from MacCormac's "Antiseptic Surgery": Water possesses no very strong attraction for carbolic acid; the latter is readily given off by it, hence watery solutions seem to act more intensely on the skin, or any surface to which they are applied. When the acid does not dissolve in twenty parts of water, but partly remains suspended in the form of oil-globules, impurity to that extent is indicated, and the solution should be filtered before using, as the undissolved particles act as a caustic.

The best way of preparing either oily or watery mixtures is to first put a few ounces of oil or water into the jar or bottle, and then add the full quantity of acid, previously melted by heat. Mix the two thoroughly, and afterward add the remainder of the oil or water, otherwise it is difficult to properly blend the oil or water with the acid.

The watery solutions are of two strengths: one being five per cent., or 1 part in 20, and the other two and a half per cent., or 1 part in 40. The five per cent. solution is employed for purifying the hands of the surgeon and his assistants before and during an operation; also to disinfect the surface of that region of the body where the operation is about to be performed, and all parts which will be included in the subsequent dressing—also for supplying the steam spray. In a solution of this strength sponges are preserved, also silk and drainage-tubes.

The 1 in 40 solution is used for the purpose of irrigating a wound,

washing the sponges used during an operation, soaking the gauze which is first applied to the surface, and for filling the tray in which the instruments required are placed. Glycerin in equal proportion to the carbolic acid may often be added with advantage to the watery solution. It helps to prevent the too rapid volatilization of the acid, and counteracts to some extent its irritating properties.

A solution of carbolic acid in alcohol, 1 to 5, is used for the purpose of purifying wounds inflicted some twenty-four or thirty-six hours before coming under treatment.

Carbolic acid and glycerin in the proportions of 1 to 5 and 1 to 10 is used as a dressing for wounds in the neighborhood of the anus, penis, etc.

Carbolic oil consists of a mixture of carbolic acid and olive oil in various proportions. The 1 to 5 oil is chiefly known as the solution in which catgut is permanently preserved. It has been shown by Koch,[1] however, that solutions of carbolic acid in oil or alcohol are absolutely inert in respect to their action on bacteric life, either on the spores or the fully developed organisms. Anthrax spores introduced into oily solutions of carbolic acid, of thymol, and of salicylic acid, in each at the end of three months were still found capable of development. Koch, however, remarks that "when the oily solution came in contact with substances containing water, as, for instance, the tissues of the human body in wounds, etc., then it undoubtedly gave up part of the acid to these, and in this way an antiseptic effect would be produced. In all cases, however, in which dry substances, such as silk, catgut, instruments, etc., have carbolic oil applied to them, not the least antiseptic effect is to be expected even upon the most vulnerable micro-organisms."

The possibility of catgut having been made from the intestines of anthracized sheep renders special caution in its perfect disinfection necessary. Zweifel, of Erlangen, Kocher, of Berne, and Volkmann, of Halle, have already reported cases of anthrax-infection of wounds by means of catgut.

The use of gauze and other materials impregnated with carbolic acid as a wound dressing will be described in a subsequent chapter (Chap. X.). The rapid deterioration of the antiseptic strength of such dressings by the volatilization of the carbolic acid has been shown, particularly by Dr. R. F. Weir,[2]

[1] *Ueber Disinfection. Mittheilungen aus dem kaiserlichen Gesundheitsamte*, 1881.

[2] Remarks on Antiseptic Dressings. New York Medical Journal, January, 1880.

of New York, who found that in gauze that had been impregnated after Lister's formula, and kept in a tight box wrapped up in rubber cloth, there remained at the end of three months but 1.44 per cent. of carbolic acid. Another specimen, similarly prepared and preserved, showed at the end of three weeks 1.82 per cent. The ordinary gauze sold at the shops was found by Kopff to have but one-half of one per cent. of acid. Only that which has been freshly prepared, therefore, should ever be used.

Advantages of Carbolic Acid as an Antiseptic.—The properties of carbolic acid which commend it for use as an antiseptic are:

1. Its *reliability*. Comparatively weak aqueous solutions, 1 to 20 and 1 to 40, may be depended upon with certainty to destroy all micro-organisms (except such most resistant spores as the anthrax, which need not be ordinarily considered in connection with wounds), while much weaker solutions suffice to prevent development as long as the reagent continues to be present.

2. Its *diffusibility*. The miscibility of the reagent-solutions with wound-secretions, and the absence of any escharotic or coagulating effect from the dilute solutions used, favor its penetration into all parts of whatever wound may be treated with it, whereby complete and thorough disinfection of all parts of the wound is certainly obtained.

Disadvantages.—1. The *local irritation* which it excites. Carbolic acid, when brought in contact with albuminous fluids, as serum or pus, forms a compound with the albumen—phenol-albuminate—so that its addition in larger quantities and in greater strength is necessary to secure complete disinfection of wounds, if they have already become septic. The irritation which the use of solutions of the required strength, 1 to 20 to 1 to 40, produces, determines increased capillary oozing, and an excessive and prolonged serous flow from the wound surfaces. In this respect its use violates one of the most important indications of wound-treatment, to diminish the amount of putrescible material in a wound. To overcome this, greater complexity of drainage, and of external dressings to a wound are demanded, and the most watchful care against the possible entrance of septic organisms rendered necessary. Eczema and erythema of the skin covered by the carbolic dressings is not an infrequent effect. It benumbs the skin, and is followed by general branny exfoliation of the superficial layers of epidermis. This is particularly likely to be disagreeably marked upon the hands of the surgeon using it.

2. Its *volatility* lessens its usefulness as an agent to secure permanent

antisepsis, making frequent renewal of the dressings necessary, which renewals violate another fundamental principle of wound-treatment, that of rest. Unless the dressings are frequently changed, organisms speedily appear in the discharges that accumulate under the dressings.[1] The necessity of restraining the volatilization of this antiseptic by enveloping the dressings charged with it in an impermeable material—macintosh—keeps the parts thus confined in a state of moist warmth, which promotes exudation and favors decomposition by maintaining a condition favorable for the occurrence of putrefaction as soon as the antiseptic is sufficiently exhausted. By keeping the skin underneath it moistened with retained secretions it establishes also a favorable channel for the introduction of organisms from without. Its volatility makes absorbent dressing materials that have been charged with it entirely unreliable for antiseptic dressings after they have been prepared for more than a few days. A surgeon in ordinary practice is thus prevented from keeping it in stock for emergencies.

3. Its *toxic* qualities. The absorption of carbolic acid in poisonous quantities is more frequently observed when large cavities or extensive wounds are washed out or are exposed to the action of the reagent under a pressure that favors its absorption. Some persons seem peculiarly susceptible to the influence of carbolic acid, and in them quite a small quantity will suffice to excite symptoms of poisoning. Children and women seem more especially liable to its noxious influence. Many fatal cases of poisoning by absorption of carbolic acid, when used as an antiseptic application, have been recorded. The severe cases are characterized by symptoms of profound collapse, which speedily terminates in death by failure of the respiration. In the less severe cases gastric derangements first appear, as loss of appetite, frequent nausea, or incessant vomiting; there is an increase, often enormous, in the secretion of saliva. More or less stupor or giddiness, noises in the head, or other signs of cerebral disturbance. The secretion of urine is diminished, and very often becomes of a dark olive-green color. It may be passed in this condition, or may become dark only after standing for some time. There is, however, no direct relation between the toxic effects of the carbolic acid and the amount of the discoloration. It is met with when there are no other symptoms; or the urine may be clear, while other well-marked signs of carbolic-acid poisoning are present. Abandonment of the use of the acid is at once

[1] Cheyne: Antiseptic Surgery, p. 238 *et seq.*

required when toxic symptoms arise. Little benefit is to be expected from any other treatment.

In Mr. Lister's practice, according to Cheyne, carbolic-acid poisoning is a thing of very rare occurrence, only two cases having been recognized in which serious toxic symptoms were due to it. The reason given for this immunity is, that Mr. Lister brings carbolic acid as little as possible in contact with wounds, applying it freely to everything which may come in contact with the wound, rather than to the wound itself. He does not irrigate wounds, nor inject them, nor even wash away the blood and dirt from the line of incision.

The importance of the disadvantages that attend the use of carbolic acid in the treatment of wounds is so great that, with the increasing knowledge of the requirements for preventing the septic infection of wounds, and of the value of other agents for that purpose, its use deserves to become very much circumscribed. Only, perhaps, for use in the antiseptic bath for the immersion of metallic instruments can it not now be replaced by less objectionable substances.

CHLORIDE OF ZINC.

The germicidal power of chloride of zinc, according to Sternberg, is but half that of carbolic acid, a strength of 1 to 50 being required to destroy the micrococcus of pus. It is very soluble in water, and its stronger solutions are powerfully caustic. It has been commonly employed in the strength of 8 to 100 (40 grains to the ounce). This, while it destroys with certainty all organisms that may be present, forms by its reaction with the albumen of the tissue to which it is applied a white translucent film of zinc-albuminate, which not only restrains exudation and protects mechanically the underlying tissue, but also forms to them an antiseptic shield that is capable of resisting for many days the development of micro-organisms.[1] The caustic effect of the reagent unfits it for use on freshly cut

[1] Kocher, in his paper on the treatment of wounds already referred to, quotes the experiments of Boillat, in which a specimen of this zinc-albuminate, covered simply with a glass-receiver and kept at the ordinary temperature of the room, showed the first evidences of the development of micrococci thirty days later than a corresponding specimen of simple albumen, although anthrax spores had been sown directly on the surface of the former. A specimen of phenol-albuminate, prepared like the zinc-albuminate, remained free from organisms only one day longer than the simple albumen.

surfaces, if their union by first intention is desired. In wounds in the vicinity of the mouth and anus, to which protective dressings are inapplicable or insufficient, its value is especially great. It has been commonly employed in the 8 to 100 strength for the disinfection of wounds that have been for some time exposed to septic influences, or in which septic change has already taken place. Kocher speaks in terms of the highest praise of the value of very dilute solutions of chloride of zinc, 1 to 500, for irrigating large suppurating cavities. The absence of poisonous properties in the reagent permits its use without limit till every vestige of pus has disappeared. By the use of some antiseptic external dressing to exclude the entrance of new infectious material to the cavities, a perfect and rapid healing of the cavity may be secured. Generally a single irrigation with the chloride of zinc solution suffices. Only when recurrence of high temperature takes place is a repetition needed.

The combination of qualities possessed by chloride of zinc, of restraining the further production of putrefiable material and of rendering whatever material of the kind there may already be present unfit to support the life of septic organisms, with certain germicidal strength, makes it an antiseptic agent of the greatest value.

SALICYLIC ACID.

Salicylic acid was introduced by Thiersch,[1] of Leipzig, as a substitute for carbolic acid, the methods of its use being the same. Though of much less germicidal power than carbolic acid, by reason of its comparative freedom from toxic qualities, the possibility of its use in greater quantities in many instances is sufficient to make it an efficient antiseptic. Wounded surfaces are not irritated by it, nor is the granulating process disturbed. The results obtained by it have not been as good as those obtained by carbolic acid. The experiments of Sternberg show that the solution of salicylic acid, 1 to 300, that has been used, is practically inert.

It has been more recently used as a dry powder-dressing with more decided antiseptic effects. It is not applicable to fresh wounds in which union by first intention is desired, as it acts mechanically to prevent apposition. It is not efficient in the prevention of erysipelas. It does not ad-

[1] *Klinische Ergebnisse der Lister'schen Wundbehandlung und über den Ersatz der Carbolsäure durch Salicylsäure.* Volkmann's *Sammlung klinischer Vorträge*, Nos. 84 and 85. 1875.

here firmly to the tissues to which it is applied, and hence is easily washed away by any increased secretion. When cavities are packed with it, in powder, and covered in by salicylic wool, the first dressing may remain in place for from one to two weeks without decomposition taking place in the wound secretions, and with rapid progress of healing. In general its use in large quantities has been unattended with toxic symptoms.

BORACIC ACID.

Boracic acid has been highly praised by the late William Warren Greene, of Portland, Me.,[1] as a reliable germicide, cheap, free from all unpleasant taste or odor, stable, and devoid of any irritating or poisonous quality within the limits of ordinary doses. By Sternberg its value was found to consist solely in its ability to restrain the development of organisms, which it possesses in a marked degree. By Mr. Lister it is used as an application to superficial granulating surfaces. It may be dissolved in water in the proportion of nearly 4 to 100 parts to form a lotion; but it finds its greatest use in the shape of borated cotton to afford a permanent antiseptic protective dressing.

ACETATE AND ACETO-TARTRATE OF ALUMINA.

The introduction of acetate of alumina as an antiseptic application to wounds is due to Maas, of Freiburg. It is cheap, unirritating, and non-poisonous, but can only be used in the moist form as it decomposes in the dry state. If ten parts of hydrate of alumina are mixed with eight parts of dilute acetic acid, and allowed to stand for twenty-four to thirty-six hours, at a temperature of from 68° to 90° F., the filtered solution obtained will be of fifteen per cent. strength. The hydrated alumina may be obtained by precipitation from a solution of common alum by carbonate of soda.

For application to wounds a solution of two and one half per cent. strength is used. Compresses wet with the solution are laid over the wound and covered in with macintosh. The amount of wound-secretion is usually very small, and the dressings required are infrequent. The aceto-tartrate of alumina is a crystallized salt, soluble in all proportions, and possessed of marked antiseptic properties. It owes its introduction as an

[1] Boracic Acid in Surgery. Boston Medical and Surgical Journal, 1880.

antiseptic to Kümmell, of Hamburg, who has used it as a three per cent. and a five per cent. solution for purposes of irrigation with children and in all cases in which the toxic qualities of carbolic acid render that agent unadvisable. As an antiseptic dressing one-half to three per cent. solutions gave very satisfactory results. Mixed with charcoal in proportions of three parts of the salt to seven of charcoal (the charcoal having been previously baked for several hours), it forms an antiseptic absorbent powder-dressing of the greatest value for filling in wound-cavities when primary union is impossible. A first dressing with the aluminated charcoal may often be allowed to remain undisturbed for one or two weeks. In small wounds complete healing will be accomplished as under a scab. It makes an exceptionally favorable dressing for wounds involving the anal region, and particularly after operations for extirpation of the rectum, in which cases the wound-cavity, after hemorrhage has been controlled, is packed with the powder, which is held in place with a layer of cotton-wool, some impermeable tissue, and a T bandage.

IODINE AND IODOFORM.

Iodine has been long in use as a topical application to wounds. In 1854 it was praised by Duroy ;[1] in 1871, Richardson advocated its use as a most valuable agent in the treatment of wounds, alleging that it deodorizes, controls discharge, destroys decomposing products, and does no systemic injury.[2] Bryant,[3] for purifying wound-surfaces has employed for years an iodine lotion made by adding twenty drops of the tincture to the ounce of water (pouring the tincture into a basin full of water, until the latter is of a light sherry color, is a sufficient practical guide), and prefers it to any other, as being always at hand, and both simple and effectual. A sponge wrung out of this lotion (made with hot water), and held to a wound for a minute, completely checks all oozing of blood, and tends more than anything else, except prolonged exposure to the atmosphere, to the formation of that glaze upon the surface of the wound which so much conduces to satisfactory repair.

---

[1] *Expériences et Considérations nouvelles pour servir à l'histoire de l'iode. Union Médicale*, Paris, T. viii., 1857.

[2] On the Science and Art of Healing Wounds. Transactions St. Andrew's Medical Graduates Association, 1871, v., p. 49.

[3] International Encyclopædia of Surgery, 1882, ii., p. 27. Article on Wounds.

The antiseptic properties of iodine, according to Sternberg's experiments are many fold greater than those of carbolic acid—as a germicide five times, and as a germ-restrainer eight times as great—but they have attracted general attention only since the introduction into use, as an antiseptic, of its compound, iodoform, the teriodide of formyl, C_2HI_3, which contains ninety-six per cent. of iodine.

Iodoform, when in solution, undergoes gradual decomposition, evolving iodine, so that when a wounded surface is covered with iodoform a kind of antiseptic reservoir is established, which, constantly and slowly giving off iodine in a nascent state, effectually hinders putrefactive changes in the wound.[1] The credit of having introduced iodoform as an antiseptic dressing, is due to Professor A. Von Mosetig-Moorhof, of Vienna, who advocated its use first in a series of articles published in the *Weiner Medicinische Wochenschrift* in 1880 and 1881, and more recently in a clinical lecture published in Volkmann's series.[2]

The advantages possessed by iodoform caused its immediate and extensive adoption; by it was introduced a new method of antiseptic dressing, the *dry-powder* dressing, which more perfectly met the requirements of a wound-dressing, than any method that had preceded it. It restrained wound-secretion and thus diminished the amount of putrefiable material in a wound; it destroyed the vitality of whatever putrefactive germs were already present in the wound, without itself irritating the wound; it was capable of forming an external, antiseptic, protective dressing; its decomposition or its volatilization was so slow that the frequency of the dressings required was greatly lessened.

Iodoform is easily soluble in ether, and in both the fixed and essential oils, less readily in alcohol, and to a very slight degree in water. It has not the least local irritant action, but exercises an anæsthetic effect upon the surfaces to which it is applied. On account of its slight solubility in water and in the animal fluids it is not adapted for disinfecting instruments and sponges, the hands of the surgeon, or the adjacent integument, or as an application to surfaces already decidedly septic. Upon fresh wound-surfaces, or upon surfaces that have been long exposed after they have been disinfected by some other agent, as corrosive sublimate, carbolic

[1] Sands: On the Value of Iodoform as a Dressing for Wounds. The Medical Record, 1882, xxi., p. 309.

[2] *Der Iodoform-Verband.* Volkmann's *klinischer Vorträge*, No. 211, January, 1882.

acid, or chloride of zinc, the powdered iodoform may be lightly dusted (from a pepper-box). A slight layer of iodoform will not interfere with union by first intention when apposition of the surfaces can be obtained. In such case, after bringing the wound-surfaces together, with such provisions for drainage as may seem best, the dressing is completed by covering the surface with several layers of iodoform-gauze, or other similar antiseptic absorbent substance. Over all a layer of some impermeable tissue, the whole confined by a snugly applied bandage. This dressing may be renewed on the second or third day, and afterward every five or eight days, or even after longer intervals, as circumstances may determine. Pain in the wound, or an elevation of temperature, after it has been for some time normal, are indications calling for a change of dressing.

In open wounds the cavities, after having been lightly sprinkled with the powder, are filled with the iodoform-gauze, and the whole covered in as before. Such wounds remain free from pain, the scanty discharge which takes place is serous in character, the surrounding integument remains free from inflammatory swelling, and the process of granulation proceeds rapidly and without interruption. When, however, the reparative process is far advanced, ultimate cicatrization is hastened by the use of some other agent.

Iodoform is especially adapted for use in the treatment of wounds involving the mouth or anal region, in which cases plugging the wound with iodoform-gauze suffices to keep it aseptic. Frequent removal of the dressing even is unnecessary.

Disadvantages of Iodoform.—1. It is *less absolute* in its power to protect wounds against the invasion of *erysipelas* than against suppuration and putrefactive disturbances.

2. Its *odor* is pervasive and lasting, and quite disagreeable to most persons. Musk, Peruvian balsam, various essential oils, as bergamot, clove, and peppermint, have been proposed as corrigents. Mosetig-Moorhof originally used Tonquin bean for the purpose. Schork says that if 0.05 gramme of carbolic acid be rubbed up with 10 grammes of iodoform, and 2 drops of oil of peppermint be added, the unpleasant odor is entirely covered and is not again developed even under a higher temperature.

3. Its *toxic qualities* early claimed attention on account of the great freedom with which the earlier employment of the agent was characterized. Various degrees of toxic action have been recorded, and experience has demonstrated that its use must be guarded with certain cautions, if risks

of fatal consequences are to be avoided. It acts by absorption into the general circulation of poisonous quantities from the wound-surfaces. Poisonous doses cause rapid and feeble heart-action, coma, and paralysis of the organs of respiration. Autopsies have demonstrated in such cases the lesions of meningitis and fatty degenerations of the heart, liver, and kidneys. But the most remarkable manifestations of poisoning in the human subject are due to perverted cerebral action, taking the form of mental derangement. Every degree of intoxication has been observed, from simple exaggeration of nervous excitability to the condition of acute mania. In the lighter cases patients are restless and uncomfortable, complaining of headache, loss of appetite, wakefulness, and the constant taste of iodoform. Such symptoms often, but not always, precede those which are met with in bad cases, which are nearly identical with the symptoms of delirium tremens. From such a condition many persons recover, while others die, often suddenly, from exhaustion or coma. No antidote to the poison has been discovered, and the only treatment of any avail is that of preventing further intoxication, and supporting the patient's vital powers by alcoholic stimulants until the crisis is past. Thus far it has not been ascertained definitely what amount of iodoform is necessary to cause poisoning, and the susceptibility to its action appears to vary greatly in different cases. Old persons are especially liable to suffer from iodoform-poisoning, while such is not the case with children, as far as can be inferred from the limited statistics thus far published. In the present state of our knowledge it should be employed with great caution, and in such a manner that it can be readily removed from the wound in case symptoms of poisoning should supervene.[1]

According to Neuber,[2] of Kiel, not more than forty-five grains of iodoform should ever be sprinkled upon a fresh wound-surface.

NAPHTHALIN.

Napthalin is a coal-tar product, much resembling paraffin in appearance, save that it is much more crystalline. It is insoluble in water or animal juices, but readily dissolves in ether, hot alcohol, and various fatty oils. Fischer, of Strassburg, first recommended it for use as an antiseptic

[1] Sands. Op. citat.

[2] *Erfahrungen über Iodoform-und Torfverbände*, etc. *Archiv für klinische Chirurgie*, 1882, xxvii., p. 757.

wound-dressing.[1] It was adopted by Professor Lücke in his surgical wards in Strassburg, and thence has come into general use. In the United States it has been made the subject of study and comment by Park,[2] of Chicago, and Fowler,[3] of Brooklyn.

It is to be used as a dry powder-dressing, being dusted, in fine powder, on the surfaces of the wound, or packed in quantities without limit into wound-cavities. Gauze impregnated with it may be used for absorbent and protective dressings.

Though its antiseptic qualities are inferior to those of carbolic acid or iodoform, yet in addition to the general advantages of the powder-dressing which it shares with iodoform, it has the great advantage that no general toxic effects ever follow its use, and that it is almost a specific against erysipelas.

It is not adapted for use in wounds the union of which by first intention is desired. To insure its protective action it is important that it be introduced into every part of the wound, and care is to be taken that its tendency to form crusts does not cause retention of the wound-secretions. Its freedom from toxic qualities commends it as a substitute for iodoform in cases in which the use of the latter agent is unadvisable or must be discontinued.

A pure article of naphthalin only should be used. Pure naphthalin remains white permanently; an impure article turns red. The application of the impure article is likely to occasion pain and irritation of the wound and eczema of the surrounding skin. No such effects attend the use of pure naphthalin.

SUBNITRATE OF BISMUTH.

The subnitrate of bismuth is advocated by Professor Kocher,[4] of Berne, as an antiseptic agent not inferior to any previously employed, and excelling all in the simplicity of its application, its certain antiseptic effect, and

---

[1] *Untersuchungen über die Wirkung des Naphthalin. Berliner klinische Wochenschrift.* 1882. xix., p. 113.

[2] Naphthalin as an Antiseptic for Surgical Dressings. The Weekly Medical Review, 1883, p. 54.

[3] Naphthalin in the Treatment of Wounds. Annals of Anatomy and Surgery, 1883, vii., p. 242.

[4] *Ueber die einfachsten Mittel zur Erzielung einer Wundheilung durch Verklebung ohne Darmröhren.* Volkmann's *Sammlung klinischer Vorträge*, No. 224.

its innocuousness. Its special field is as an application to fresh wounds for restraining the development of organisms, while for the disinfection of hands, instruments, surrounding skin, and of wounds that are already septic, other agents must be employed. Its insolubility prevents its effect from extending beyond the region to which it is directly applied, therefore, when it is used, special care to prevent accumulation of blood and wound-secretion is necessary. This Kocher accomplishes by leaving all wounds open temporarily, protected by a bismuth dressing, and closing them only after the first outpouring of the secretions is arrested. The bismuth exercises a desiccating and astringent effect upon the wound-surfaces and assists in limiting the amount of secretion. Under its use the secretion from the wound-cavity ceases in from twelve to thirty-six hours. Wounds may then be closed without any further provisions for drainage. It is to be used suspended in water; the salt should have been finely powdered, with special care for the purpose; should then be gradually and most thoroughly triturated with water, till all grittiness has disappeared, and an emulsion-like mixture can be produced by simply adding water. If a bottle containing such a mixture is shaken, the bismuth will be uniformly and rapidly suspended through the fluid.

A one per cent. watery mixture, thus prepared, will answer all the demands of thorough antisepsis. In the course of operations the surfaces of the wound may be moistened at intervals with the lotion by sprinkling it from a bottle, and when the dressings are changed similar manipulations may be repeated. The application of the salt to a fresh wound-surface causes at first a smart burning sensation, but after the first application this is no longer experienced. After the lips of a wound have been brought together, bismuth may be spread upon the line of sutures in the form of a thick paste applied by means of a brush. This method may also be followed when a wound has healed to a narrow, superficial granulating surface. In recent wounds the dressing is completed by applying a protective covering of gauze or other absorbent material, which has been dipped in a ten per cent. mixture of bismuth, the moisture being pressed out before being applied; over this a layer of cotton-wool, and some impermeable tissue, the whole kept in place by a roller bandage.

The subnitrate of bismuth should not be applied in unlimited quantities. It is absorbed to some extent by fresh wound-surfaces, and if applied in large quantities to extensive surfaces will produce toxic effects,

characterized by acute stomatitis analogous to the chronic form of lead-poisoning, intestinal catarrh, and desquamative nephritis. There may be slight transient renal disturbances produced, as manifested by a blackish discoloration of the urine, with albumen and epithelial casts, unattended by other general symptoms. These toxic effects subside rapidly after the removal of the bismuth, without leaving any permanent after-effects. None of them have been occasioned since the lavish use of strong mixtures and the packing of cavities with the undiluted powder has been abandoned.

PART I.

IN GENERAL.

SECTION II.

THE PRACTICE OF WOUND-TREATMENT.

CHAPTER VI.

THE ARREST OF HÆMORRHAGE.

Spontaneous Hæmostasis—*Surgical Hæmostasis*—Exposure to Air—Cold—Hot Water—Iodine—Alcohol—Turpentine—*Mechanical Pressure*—Compresses—Tampons—Acupressure—Forcipressure—Ligation—Catgut Ligatures—*Plugging Vessels*—Torsion—Coagulants—The Cautery—*Interrupting Blood-current*—Position—Forced Flexion—Digital Compression—Tourniquets—Elastic Bandage—Acupressure—Ligation—Cardiac Sedatives.

The conditions which demand the attention of the surgeon in the case of every wound present themselves to him in the following order:

1. The arrest of hæmorrhage.
2. The general condition of the patient.
3. The cleansing of the wound.
4. The apposition of its surfaces.
5. The means of protection required to prevent disturbance of the healing.
6. The relief of disturbances of the healing, if any be present.

THE ARREST OF HÆMORRHAGE.

In most wounds hæmorrhage is an immediate symptom, and, in many, demands the instant and active interference of the surgeon for its control.

Its extent will depend on the number, size, and character of the wounded vessels; and the character of the surgical aid demanded will depend upon the extent to which the natural tendencies to spontaneous arrest are deficient, the object of the surgeon being simply to supply such deficiencies in the manner that may cause the least disturbance in the future repair of the wound.

In every wound a spontaneous effort at hæmostasis takes place, in

which the wounded vessels, the perivascular tissues, and the blood itself are all engaged. A divided artery contracts and greatly diminishes its lumen and withdraws itself within its sheath. A vein collapses so that its walls fall together. Connective-tissue strands and muscular fibrils fall over the cut ends of the vessels and tend to entangle the fibrin of the escaping blood. The irritated muscular and elastic tissue of the wounded region contracts and compresses the vessels that it embraces. This spontaneous vascular contraction, aided by the compression exercised by the contraction of the surrounding wounded tissue, suffices alone to check hæmorrhage from the capillaries in healthy tissues. As the result of the action of these influences, the bleeding, though very free at the moment of the infliction of the wound, quickly becomes greatly diminished in amount. When vessels too large to be controlled by such influences are wounded, and the hæmorrhage continues until much blood is lost, the force of the heart's beat becomes weakened, until the impulse to the blood current which it gives may become too feeble to send the wave of blood as far as the wounded vessel, and thus the bleeding spontaneously ceases. The blood itself brings the crowning agent for completing the process of arresting its own flow, in the coagula that begins to form as soon as the first vigorous gush is slackened. These become fixed by the irregular surfaces of the wound, and, extending into the interior of the severed vessels as far as to the first collateral branches, temporarily plug them up. These coagula serve only a temporary purpose, those within the vessels becoming eventually replaced by the new granulation-tissue which the wounded tissue of the vessels, and especially their inner tunics, are stimulated to produce for the ultimate permanent repair of the wound.

The effective exercise of this quality of coagulation for arresting hæmorrhage is thwarted only when the rapidity of the blood current that reaches the opening in the vessel is too great to permit a coagulum to accumulate, or its force is so great as to sweep away whatever may have already been formed. This latter cause is especially illustrated by the recurring hæmorrhages that take place from vessels that had ceased to bleed when the heart's action had become faint through shock or loss of blood; with the establishment of reaction the heart-beats become strong again, and the impulse of the blood-waves become sufficiently great to sweep away the coagula previously formed; the hæmorrhage recurs, and though it may soon cease, it will continue to recur, unless adequate means to prevent it be taken, until the patient dies of anæmia.

The agencies which nature provides for the spontaneous arrest of hæmorrhage include, therefore, the following:

1. Immediate diminution in the size of the opening by the intrinsic contraction or collapse of the walls of the injured vessel.
2. Immediate and direct compression from without by contraction of surrounding tissue.
3. Secondary diminution in the force and volume of the blood current by heart faintness.
4. Temporary plugging by coagulation of the escaping blood.
5. Permanent occlusion by the exudation and organization of plastic material at the seat of the wound in the vessel.

The agencies which the surgeon likewise will find of benefit must derive their value either from the compression they produce, the contraction of the vessels they excite, the interference with the blood supply they accomplish, or the increased coagulability of the blood they occasion.

The means for arresting hæmorrhage naturally divide themselves, therefore, into means of *direct vascular contraction*, of *compression*, of *plugging* the open orifice of the vessel, and of *interruption to the blood current*.

Means of Direct Vascular Contraction.—This class includes contact of atmospheric air, cold and hot applications, and such local irritants as iodine, alcohol, and turpentine.

Exposure to Air.—The contraction of soft parts when exposed to the air is very marked, and the continued exposure of a bleeding surface to cool air produces a strong hæmostatic effect, which is increased if the air is kept in motion as by a fan. When a wound is filled with coagula, underneath which bleeding is still taking place, the thorough removal of the clots and the exposure of the bleeding points are often speedily followed by the cessation of the hæmorrhage. In all cases where there is present hæmorrhage, the first duty of the surgeon is, if possible, to fully and clearly expose the bleeding point by the removal of whatever clots, compresses, or bandages may have previously accumulated in or about the wound. Should the mere exposure to the air not be sufficient to cause the hæmorrhage to cease, it is in the best position to receive the benefit of other applications. Where the possibility of recurrence of hæmorrhage in a wound is to be feared, the free exposure of the wound-surfaces to the air for some hours furnishes the most reliable means of guarding against it. Though the wound be not closed until after many hours, the process of healing may yet continue without material disturbance, and union by first intention be secured.

Cold as a hæmostatic has always been recognized as of great value. It may be applied by irrigating the wound with cold water, by applying sponges or compresses wrung out of cold water, by the application of small pieces of ice to the bleeding surface, or by enveloping the part in bags containing pounded ice. Although cold, thus applied, causes the soft parts to contract and the blood-vessels to shrink, its application for any length of time tends to increase shock, and to depress the vitality of the wound-surfaces, and thus to diminish the vigor of the subsequent repair of the wound. The after-effect of the cold is to lessen the tone of the capillaries and predispose them to inflammatory conditions. The use of cold applications for hæmostatic purposes is therefore to be resorted to only in exceptional cases in default of other resources.

Hot water is even more efficient as an hæmostatic than cold. Attention has but recently been called to its merits by Keetley,[1] in England, and by Hamilton[2] and Hunter,[3] in the United States. It combines in an eminent degree the properties of stimulating the contraction of the soft tissues of the exposed surface, and of exciting the vital contractility of the vessels both directly by contact, and indirectly through the vaso-motor nerves. It produces a permanently stimulating effect upon the vitality of the surfaces to which it is applied; it favors primary union in the wound; and in no class of cases is its value more marked than in those of threatened shock and of exhaustion from hæmorrhage. The temperature of the water should be as great as can be borne by the hand without pain, from 125° to 139° F. Hamilton used sponges dipped in hot water at almost a boiling temperature, and applied by forceps to the bleeding points. But as the water is intended to act as a stimulant, and not mechanically by coagulating the albuminoids of the blood, so high a temperature is not needed. The most effective means of applying it is by means of compresses of muslin or linen, or towels of size sufficient to cover the whole wound-surface, that all parts may experience the effect of the application simultaneously. To obtain the full effect, it is important that one compress be quickly succeeded by another till permanent arrest of the bleeding is secured.

Hot water answers the requirements of a wound-application more perfectly than any other agent. The simple precaution to free it from hurtful

[1] London Practitioner, February, 1879.

[2] Buffalo Medical and Surgical Journal, April, 1879.

[3] Philadelphia Medical Times, November 22, 1879.

organisms before it is used is alone needed to make it entirely unobjectionable.

Iodine added to hot water increases its hæmostatic effect, while it also disinfects it. Sufficient of the iodine may be poured into a basinful of water to make the latter of a light sherry color. A sponge wrung out of this lotion (made with hot water), and held to a wound for a minute, completely checks all oozing of blood, and tends more than anything else, except prolonged exposure to the atmosphere, to the formation of that glaze upon the surface of the wound which so much conduces to satisfactory repair.[1]

Alcohol excites to action the contractility of the vessels and the perivascular tissues, while it acts, in addition, as an antiseptic. It may be applied on a sponge pressed upon the bleeding surface.

Turpentine is strongly recommended by Billroth[2] as capable of exciting a peculiarly energetic contraction of the divided capillaries. It may be applied on bits of absorbent material pressed against the bleeding points. It is a heroic remedy causing severe pain, and exciting severe inflammation in the wound and its vicinity.

MEANS OF COMPRESSION.—Compression may be accomplished by agents that either stimulate the wounded tissues to more energetic contraction, or that may exert direct mechanical pressure upon the bleeding surfaces.

The first class of agents includes again atmospheric air, cold and hot applications, and certain irritants, since these agents cause the surrounding tissues to contract with the same energy as they do the bleeding vessels. The contraction of the perivascular tissues is a very important element in accomplishing the spontaneous arrest of bleeding. The range of application and the value as hæmostatics of the agents which have been considered as stimulants to contraction of the vessels directly is thus greatly increased by their effect upon the surrounding tissues, through the contraction of which physiological compression of the vessels is secured. To supplement this, however, means of compression, applied from without, are necessary whenever the size of the vessels is too great to admit of their control by physiological means, or the wounded tissues are non-contractile. This is supplied by some form of mechanical pressure, the consideration of the varieties of which is next to be taken up.

[1] T. Bryant: Article on Wounds. Internat. Encyclopædia of Surgery, vol. ii., p. 27.

[2] Surgical Pathology (Hackley, 1871), p. 36.

Mechanical Pressure.—Properly applied pressure is sufficient to control any hæmorrhage. It may be applied by means of compresses, tampons, bandages, the fingers of the surgeon, needles thrust into the tissues, forceps, and ligatures. The method of its application will depend on the character and anatomical relations of the bleeding vessels; when the bleeding comes from several points, or when it is a general oozing, which persists notwithstanding the use of means to excite tissue contractility in the wound, a compress is of great value.

Compresses may be made of any substance that permits of being formed into a firm pad of proper size to be introduced into the wound. Folds of linen or cotton cloth are generally available. Sponges and masses of charpie are often used. All clots should be turned out of the wound, and the first layer placed directly upon the orifices of the bleeding vessels. Each additional layer of the compress should be larger than the preceding, as it is built up till it projects above the surrounding integument. The whole should then be firmly bandaged. In cases where compresses are applied to wounds of a limb, the roller-bandage should invariably first be applied at the distal extremity of the limb, and be carried up the limb, over the compress and above it for some distance.

Compresses are to be considered only as temporary expedients, for their use is in violation of every principle of wound-treatment except that of hæmostasis. At the earliest moment they should be removed from the wound. If the wounded vessels are of such size as to render a recurrence of the hæmorrhage from them likely to take place, they should be secured by ligature as soon as the necessary procedures are practicable.

In wounds of slight extent sufficient compression to control bleeding may often be exerted by bringing the surfaces into apposition by sutures, and then supporting them by compress and bandage applied upon the surface.

Tampons are plugs which are crowded into cavities, such as the nares, the rectum, or the vagina, from some part of whose walls bleeding is taking place. They act by the direct pressure which they exert upon the bleeding vessels.

Hæmorrhage from larger arteries and veins is best controlled by compression limited to the bleeding vessel, and applied directly to it. The finger of the surgeon instinctively applies itself for the purpose of making such compression upon the orifice of the severed vessel, and, for immediate temporary hæmostasis, by its intelligence, its power of properly graduating

the compression to the needs of the case, and the minimum amount of disturbance which it inflicts upon the adjacent tissues, is employed with great advantage. When prolonged compression is needed, or several vessels require attention, other agents are required. Those that are employed are needles, forceps, and ligatures.

Acupressure.—Needles or pins may be thrust into the tissues so as to compress the extremity of a bleeding vessel, either by transfixing the tissues when in a state of tension, and securing pressure upon the vessel against the needle by the force of the elastic recoil of the tissues, or by affording a solid substance against which pressure can be made by other agents.

The attraction of general attention to the use of acupressure is due to Simpson,[1] of Edinburgh, who advocated it as a means of diminishing the amount of dead tissue left in a wound, of restricting suppuration, and of promoting early union in wounds. By the pressure of the pin the vessel is not lacerated, nor the vitality of any portion of it destroyed, and before it can become a cause of suppuration the pin may be withdrawn and the wound left free from the presence of any foreign body as an irritant, or mechanical impediment to repair. The compression with pins need not be prolonged for more than twenty-four hours upon vessels of small calibre, nor upon such vessels as the brachial or superficial femoral for more than forty-eight hours.

Any smooth sharp-pointed pin of sufficient length to transfix the tissues suffices for use in the practice of acupressure. A large shawl-pin, as in Fig. 4, by its smooth, globular, glass head, stoutness, length, and smoothness, answers perfectly for the purpose.

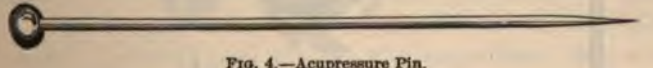


FIG. 4.—Acupressure Pin.

The simplest method of applying acupressure is to pierce the tissues so as to bring the point of the pin out on the surface of the wound close to the side of the bleeding vessel, and then, having carried it over the vessel, to lift its head, so as to depress strongly the point and thrust it onward into the tissues, close to the vessel on the other side. (See Fig. 5.) The force of the pressure exercised by the pin thus applied, will depend

[1] Acupressure; a New Method of Arresting Surgical Hemorrhage. Edinburgh Medical Journal, 1860, v., p. 645.

upon the amount and the elasticity of the tissue transfixed by it, and by the resisting character of the tissue against which the pressure is made. It is most effective when the pin is carried through the skin, so that the

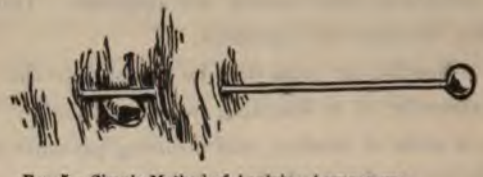


FIG. 5.—Simple Method of Applying Acupressure.

latter is stretched between the points through which the pin passes, and when the vessel is pressed against a bone. When the skin is transfixed, and still the pressure is not sufficient to arrest the hæmorrhage, the constriction can be increased by throwing a ligature tightly around the pin, on the outside, as in the operation for harelip. When the tissues are lax and do not afford sufficient counter-pressure, their resistance can be increased by twisting them, and by giving the pin different directions in different parts of its course as it is inserted. Two methods of accomplishing this are illustrated in Figs. 6 and 7.

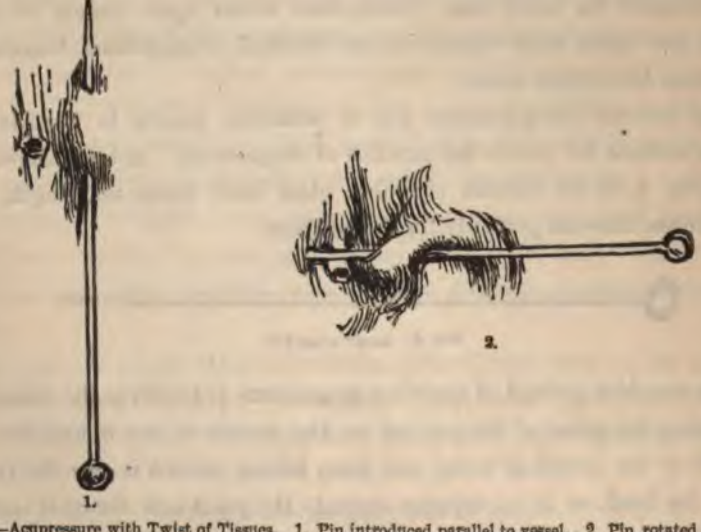
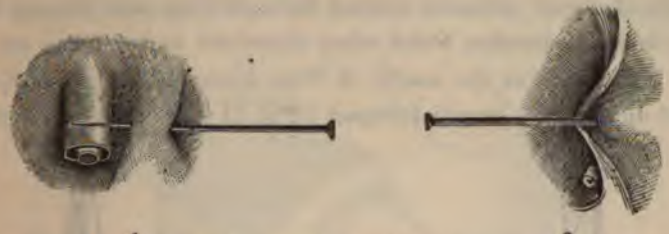


FIG. 6.—Acupressure with Twist of Tissues. 1. Pin introduced parallel to vessel. 2. Pin rotated through a quarter-circle and, after having been carried over vessel, thrust into tissues.

Other variations in the method of applying acupressure may suggest themselves according to the particular relations of the bleeding vessel.

Forcipressure.—A bleeding vessel may be seized and compressed by

suitable forceps, and not only the temporary but also the definitive arrest of the bleeding be secured without other agents. The distinctive appellation of forcipressure was given to this method by M. Verneuil,[1] of Paris,



1. 2.

FIG. 7.—Acupressure with Twist of Tissues. 1. Pin introduced transversely to vessel, its point ready to be thrust into tissues on opposite side. 2. Pin entered and reversed, twisting tissues and compressing vessel.

in a communication made to the Société de Chirurgie in 1875, in which he reports twelve observations of hæmorrhages which he had repressed by means of forceps left from two to ten days in the wound. The writings and practice of Péan,[2] of Paris, Koeberlé,[3] of Strassburg, and of Spencer Wells,[4] of London, have served to establish the value of the practice and to attract to it the attention which its merits deserve. The *serres-fines*[5] (Fig. 8) and *serres-fortes*, or *compressivpincetten*[6] (Fig. 9) of previous sur-

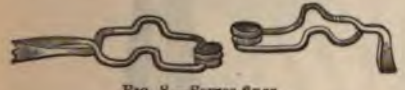


FIG. 8.—Serres-fines.

FIG. 9.—Serre-forte, or Compressivpincette.

geons, which had been used for the temporary compression of bleeding vessels, the elastic recoil of their branches when separated being the force relied upon for pressure, had been found inconvenient by reason of their

[1] *Bulletins et Mémoires de la Société de Chirurgie. Nouvelle Série. Tome i.* 1875.

[2] *De la Forcipressure, ou de l'application des pinces à l'hémostasie chirurgicale, d'après les leçons professées pendant l'année* 1874, *par M. le Docteur Péan.* Deny & Exchaquet, 8vo, pp. 72. Paris: Germer Baillière. 1875.

[3] *De l'hémostase définitive par compression excessive.* 8vo, pp. 56. Paris: J. B. Baillière et Fils. 1877.

[4] Forcipressure and the Use of Pressure-Forceps in Surgery. British Medical Journal, June 21, 1879.

[5] Vidal (de Cassis): *Traité de Pathologie externe. Tome i.*, pp. 71 and 163. Paris, 1851.

[6] Angelstein: *Ueber Compressivpincetten und ihren Gebrauch behufs vorläufiger Blutstillung.* V. Graefe & Walther's *Journal der Chirurgie*, xvii., p. 161. Berlin. 1831.

small size, and unreliable from the feebleness and variableness of their elastic spring. The hæmostatic forceps of Péan, Koeberlé, and Wells are alike in substituting for the uncertain recoil spring of the old instruments the force of direct pressure exerted through long and strong, though slender, levers as handles, which when closed are locked by an automatic catch. Fig. 10 shows the model of Péan, from which that of Koeberlé does not differ in any essential respect; Fig. 11 that of Spencer Wells.

Fig. 10.—Hæmostatic Forceps of Péan.

Fig. 11.—Hæmostatic Forceps of Spencer Wells. ¾ size.

In seizing a bleeding vessel with these forceps no effort need be made to exclude fibres of surrounding tissue if the vessel be small.

The length of time during which the forceps should remain in place in order to secure permanent hæmostasis varies much. Those which have been applied upon the arterioles of the skin, connective tissue, and muscles, and upon veins, except in case of the great venous trunks, may usually be removed in a few minutes after their application. Forceps placed on arteries of medium size may be withdrawn from six to twelve hours after the operation. Upon the main arteries of the limbs, including the

femoral, M. Péan advises that they be left from two to four days. In operation wounds they find their most valuable field by reason of the time and blood that they economize through the facility and certainty of their immediate application to each vessel that is wounded. In large operations,

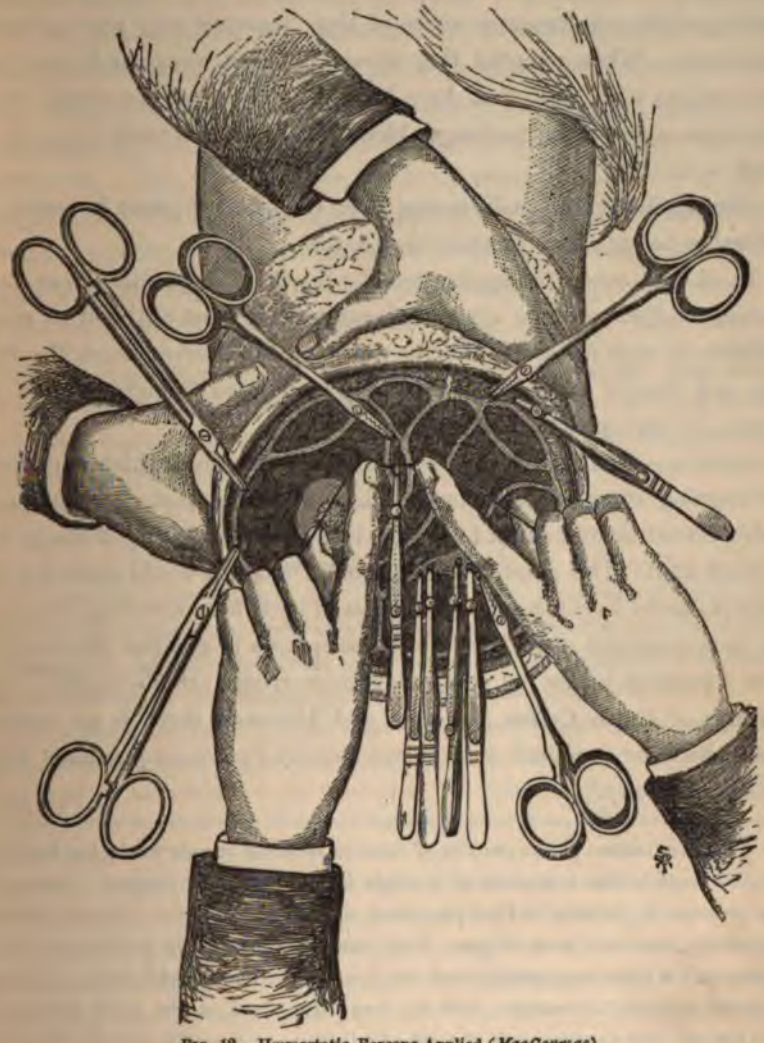


Fig. 12.—Hæmostatic Forceps Applied (*MacCormac*).

as in an amputation of the thigh, or the extirpation of a large tumor, though many forceps may have been applied and remain hanging from the wound-surfaces, in the majority the hæmostasis will prove to have been definitive by the time the operation is completed, so that the forceps may

then be withdrawn without need of other means to maintain closure of the vessel. Fig. 12 shows the manner of their use for controlling hæmorrhage in the course of operations.

These forceps, when left in wounds, are easily supported by the dressings so as not to drag upon the tissues; rarely do they cause any distress to the patient, who becomes aware of their presence only when they are withdrawn. When removed they should be taken away one by one with care, and, as soon as it shall have become certain that the vessels which they were compressing no longer bleed, the dressing should be made as usual.

The application of such forceps upon tissues most prone to resent interference has not been productive of harm.

In all cases where the application of a ligature is impracticable or undesirable, forcipressure may replace advantageously most of the other means available in such cases. It may be used so as to shorten much the duration and danger of operations, and, by leaving no foreign body in the wound, favors repair by first intention.

Ligation.—The last method remaining to be noticed which is available for exerting compression upon bleeding vessels is that of encircling it with a thread thrown about its exposed extremity, and tying it firmly with a secure knot. This constitutes ligation. Though it would seem that this method should have instinctively suggested itself for controlling the bleeding from a severed vessel, and though traces of a theoretical knowledge of it as a possible means for controlling hæmorrhage are discernible in the writings of Galen, Celsus, Avicenna, and Albucasis, there is no evidence that it was ever practised until it was used by Paré in amputations in the sixteenth century.[1]

---

[1] The introduction of the practice of ligating bleeding vessels marks the first great advance made in the treatment of wounds in the history of surgery. During the ages previous to the time of Paré the actual cautery had been the principal means of staunching traumatic hæmorrhage. Paré himself mentions his previous use of the cautery as "a thing very horrible and too cruel to be mentioned" (*chose très horrible et cruelle seulement à raconter*, book x., chap. xxvi.), and, in the same chapter, relates his own first experiment in the use of a ligature to close the vessels after amputation of a limb, as follows: "Now I advise the young surgeon to abandon such cruelty and inhumanity in order the rather to follow this method of mine, with which it has pleased God to acquaint me without my ever having seen it done by any one, nor spoken of, nor mentioned, except by Galen, in the fifth book of his *Method*, where he writes that it is necessary to tie the vessels on the side toward their roots, which

The method of Paré was to seize the vessels with suitable forceps (a thing not difficult to do—he says—because the blood can be seen spouting from them), draw them out from the flesh into which they have retracted and become hidden, and then tie them with a stout double thread. Although Paré thus brought this procedure very nearly to the degree of perfection that it has now attained, the prejudices of his contemporaries, and the erroneous methods of practising it followed by his pupils, caused it to rapidly fall into discredit, so that a hundred years later the surgeons of the Hôtel-Dieu were still to be found always employing the cautery after amputations.[1] The supposed dangers from secondary hemorrhage, from too rapid fall of the ligature, if applied directly to the vessel, caused Paré's most distinguished pupil, Guillemeau, to abandon the simple method of his preceptor and to practise, instead, mediate ligation, enclosing a mass of adjacent tissue, together with the vessel, in the ligature. The effect of

---

are the liver and the heart, in order to staunch the great flow of blood. Now, having many times made use of this way of serving the veins and arteries in recent wounds which bled, I thought that it would be well to do as much in the extirpation of a limb. Having conferred on this matter with Stephen de la Rivière, Surgeon in Ordinary to the King, and with other surgeons from Paris, and having declared to them my opinion about this, they advised that we should make the experiment on the first patient that should be offered, the more since we could have the cauteries all ready for use in case the ligature should fail. This I practised on the spot on several with very good result; and again, some days later, in the person of a postilion servitor from Brusquet, named Pirou Garbier, whose left thigh was amputated four fingers above the knee for an inflammation which had supervened upon a fracture.

"In conclusion I counsel the young surgeon to abandon this miserable way of burning and roasting (unless some remnants of gangrene compel it), admonishing him to no longer say, 'I have read it in the writings of the ancients, I have wished to act in accordance with the teachings of my old fathers and masters, following whose practice I cannot err.' This I grant, if thou wilt listen to thy good master, Galen, in the passage already alluded to, and to those like it; but if thou wishest to stop with thy father and thy masters for authority for bad practice, being willing to always continue therein, doing just the same as is usually done by them in all things, thou shalt render an account for it before God, and not before thy father or thy good masters, who treat men after so cruel a fashion."—*Œuvres complètes d'Ambroise Paré, tome* ii., p. 230. Ed. Malgaigne.

The date at which the adoption of the practice of ligation was made by Paré is fixed approximately by Malgaigne to have been about 1560, since the edition of his works published in 1552 mentions only the cautery as a means of arresting hemorrhage, and that of 1564 contains for the first time mention of the ligature.

[1] Manec: *Traite de la Ligature des Artères*, p. 2. Paris, 1836.

such a procedure was to assist the more surely in bringing the use of the ligature into disrepute. Excruciating pain, muscular spasms, and violent local inflammations were provoked by its use in such a way, while the speedy loosening of the ligature, as it cut the interposed flesh, in a few days, often determined a mortal hæmorrhage. Eight out of every ten cases of amputation thus treated died. Mediate ligation in its turn, therefore, fell into discredit, and was either abandoned almost entirely or used in combination with styptics and escharotics. The surgical world in the early part of the eighteenth century was employed in a search for hæmostatic agents, but the fear of a recurrence of the bleeding when the ligature should become detached still deterred surgeons from its use until the powerful authority of Sharpe,[1] in England (1760), and of Desault, in France (1780), restored it to confidence and brought it again among the acknowledged resources of wound-treatment.

Wide and flat ligatures, their size proportioned to the volume of the vessels, were at first deemed essential, lest the vessel should be too rapidly cut through. It remained finally for the present century to demonstrate, by the experiments of Jones,[2] that a small, round ligature was the best form to use in all cases for the arrest of hæmorrhage. The conclusions of Jones having been accepted and put in practice by Abernethy and Astley Cooper, the stout thread of Paré was restored, and the original method of that surgeon, after a lapse of two hundred and fifty years, became again the rule of surgery. Nevertheless, it still remained that the application of a ligature, however done, introduced a foreign body into a wound, and hence was to be deprecated, on account of the disturbance of the repair of the wound which it produced, both directly and indirectly, for its final separation and removal from the wound necessitated a process of ulcerative absorption of the vessel which it constricted.

The part of the vessel beyond the ligature, when it is applied upon the cut extremity, is also deprived of nutrition, and, dying, must be thrown

---

[1] This celebrated surgeon to Guy's Hospital, in his Critical Enquiry into the Present State of Surgery, formally advocated the employment of the ligature for the arrest of hæmorrhage from wounded arteries, in preference to styptics or the cautery, on the ground that "it was not as yet universally practised amongst surgeons residing in the more distant counties of our kingdom."

[2] A Treatise on the Method employed by Nature in suppressing the Hæmorrhage from Punctured and Divided Arteries, and on the use of Ligatures. By J. F. D. Jones, M.D. 8vo. London, 1805.

off as a slough. Suppuration is the necessary attendant of these conditions, and when, as is usual, the ligature thread is left hanging from the wound until the knot has ulcerated itself loose, there is maintained a suppurating sinus throughout its track which favors the development of serious septic conditions in the wound.

Practically the evils resulting from these unfavorable conditions, incident to the use of a ligature, are overcome in the great majority of cases by the natural reparative powers of the body, and ultimate healing is secured after a more or less prolonged period of suppuration and contest with inflammatory and septic accidents of more or less severity.

On account of the interference with healing produced by the ligature, importance has been given to those substitutes for it which in any degree diminish the elements of disturbance produced by the means needed for fulfilling the supreme indication of arrest of hæmorrhage. It is this which has given to acupressure and forcipressure, and torsion—a method yet to be noticed—their chief importance. No substitute for the ligature, however, has been able to obtain a permanent place in the confidence of surgeons, and it will undoubtedly always remain the chief resource for arresting hæmorrhage from vessels of any size. It is simple and easy of application, it is certain as a hæmostatic, and the materials for it are to be found in every place.

Of far greater importance than the attempts at providing a substitute for the ligature have been the results of studies to improve the ligatures themselves, striving to secure for the use of the surgeon a material strong and efficient for the compression of the vessel, as long as needed, unirritating while it is performing its work, not hindering immediate union, and, finally, capable of spontaneous absorption by the tissues in which it has been buried.

A thread of any material which can be tied with sufficient firmness and closeness to effectually strangulate a vessel, may be used as a ligature, and when the emergency presses there may be no choice left as to a selection. For general use silk thread—round, smooth, well twisted, uncolored, and sufficiently strong to stand considerable traction—has been preferred. In order to reduce to the minimum quantity the amount of tissue to be removed by ulceration, it is important that the thread be no larger than is necessary to give it the strength required to stand the strain put upon it when it is tied. For small vessels the thread need not be larger than common sewing-silk; for larger vessels, as the femoral, iliac, or axil-

lary arteries, a somewhat stouter thread—saddler's silk—is needed. After the ligature has been tied, it has been customary to clip off one end close to the knot, and to bring out the other at the nearest angle of the wound, or, if that was too remote, at any more convenient point, where it has been necessary to permit it to remain until the ligature has become disengaged from the vessel within by its ulcerative division. To accomplish this, a period of from three days to three weeks, according to the size of the vessel, has been necessary. The amount and nature of any other tissue that may have been included in the ligature together with the vessel, will also influence the time of its detachment. With the idea of lessening the evils consequent upon such a prolonged residence of an irritating thread, Physick,[1] of Philadelphia, in 1814, began to use ligatures made of leather, with the expectation that such animal material would be less irritating, and would undergo softening and absorption. In the year previous, 1813, Dr. Thomas Young, of Edinburgh, in his "Introduction to Medical Literature," wrote: "I have often wished to try ligatures of catgut, which might be absorbed," but no record of any such test having been made by him is given.

After Physick, Jameson, of Baltimore, adopted the animal ligature, using buckskin cut into narrow strips and firmly rolled. These, after numerous experiments and clinical observations, he declared to be decidedly

[1] The following is Physick's own report of his use of animal ligatures in a communication by him to The Eclectic Repertory, 1816, vol. vi., p. 389:

"Several years ago, recollecting how completely leather straps, spread with adhesive plaster, and applied over wounds for the purpose of keeping their sides in contact, were dissolved by the fluids discharged from the wound, it appeared to me that ligatures might be made of leather, or of some other animal substance, with which the sides of a blood-vessel would be compressed for a sufficient time to prevent hemorrhage; that such ligatures would be dissolved after a few days, and would be evacuated with the discharges from the wound. Under this impression I requested Dr. Dorsey to try the experiment on a horse by using a ligature of buckskin. This was found to answer every purpose and came away in a few days.

"Dr. Dorsey, in several operations in which I have assisted, has used ligatures of French kid, which he finds stronger than any other leather. He has it cut into narrow strips, stretches them, and peels off the colored polished surface. No hemorrhage has taken place in any instance, and the ligatures are found dissolved at the end of two or three days."

From this period—1816—he continued to employ animal ligatures almost exclusively up to the time when he left off operating. Memoir of Physick, by Randolph, p. 85.

superior to all other ligatures,[1] and, before his death, had applied them to all the accessible arteries of the body.[2] Animal ligatures of various kinds were occasionally used by other isolated surgeons during the fifty years which followed Physick. Silk-worm-gut by McSweeney, in 1818,[3] and by Fielding, in 1826;[4] catgut, by Sir Astley Cooper, and fibres from the sinews of the deer, by Eve, of Nashville, were thus used; but not until 1869, when Lister published the results of his experiments with catgut ligatures,[5] and incorporated them into his method of antiseptic wound-treatment, did the full value, and range of the use to which animal ligatures could be put become generally recognized. Equally with catgut the parallel strands of connective tissue which make up the tendons of different animals have been found to answer an excellent purpose. Marcy,[6] of Boston, praises those from the moose or caribou, of Maine, as most satisfactory. The tendon from the back of the buffalo and from the whale answer equally well. The tendon of the tail of the fox-squirrel of the Southern States gives fibres of much strength and as fine as silk. I have received from Dr. Marcy specimens of fibres from the tail of the kangaroo, which excel all others in the qualities desired for a ligature. Though these tendinous ligatures have the advantage of being much stronger than catgut, equal weights being used, and of softening less quickly, yet properly prepared and seasoned catgut may always be safely trusted; and since it is a staple article of commerce, to be had all over the world in abundance, comparatively cheap, and easily prepared and manipulated, it has maintained itself as the kind of animal cord best adapted for general use as a ligature, and hence requires more extended notice.

Catgut Ligatures.—Catgut is the submucous cellular tissue of the intestines of young lambs, which, after having been cleansed in an alkaline bath and bleached by sulphurous acid, is twisted into a cord and dried. As it

---

[1] Gross: System of Surgery, 1882, vol. i., p. 657.

[2] Agnew's Surgery, 1878, vol. i., p. 173.

[3] Experiments in Favor of a New Substance for Tying Arteries, and for Suture. Edinburgh Medical and Surgical Journal, 1818, vol. xiv., p. 597.

[4] On the Use of a New Substance (Silk-worm-gut) for Securing Divided Arteries. Transactions Medico-Chirurgical Society, vol. ii., p. 340. Edinburgh, 1826.

[5] Observations on Ligature of Arteries, on the Antiseptic System. Lancet, April 3, 1869.

[6] Animal Ligatures. Annals of Anatomy and Surgery, 1881, vol. iv., p. 232.

comes from the maker it is entirely unfit for use as a ligature, for when bathed in the secretions of the wound it quickly becomes so soft and pulpy that a knot will not hold. By suitable preparation or seasoning, however, its qualities may be so altered that immersion in blood-serum will no longer make it pulpy, but that it will continue to retain its form and tenacity for a somewhat prolonged period, during which its removal is being slowly accomplished by the gradual erosion of its surface by the active tissue-cells by which it is surrounded. Thus compression of the tied vessel is insured throughout the whole time that the process of its repair is transpiring.

Experience has shown, also, that it is possible to over-prepare the catgut so that it may become too rigid and difficult of absorption, and may provoke irritation, and suppuration in the wound. The following is the method advised by Mr. Lister [1] for the preparation of the gut, and which he recommends as certain to avoid the evils of over-preparation, while it obtains all the tenacity and durability needed to fit it for a ligature. A solution is to be made, containing, of

Chromic acid	1 part.
Water	4,000 parts.
Carbolic acid	200 parts.

As soon as the ingredients are mixed, enough of the catgut should be immersed in it to equal in weight the amount of carbolic acid used. The gut should remain in the solution for forty-eight hours only, at the end of which time it should be removed, dried, and then kept for use in carbolic oil, 1 to 5. The gut should be kept on the stretch, by tying the ends of each hank to two fixed points in a room, while it is drying, otherwise its strength will be seriously impaired by an uncoiling of its twist while drying.

The effect of a longer immersion in the watery solution of carbolic acid would be to "over-prepare" the gut, but after its immersion in the oily solution it keeps unchanged for an indefinite time.[2]

---

[1] The Catgut Ligature. British Medical Journal, February 5, 1881, p. 183.

[2] In the course of some remarks made at a meeting of the London Clinical Society, which are reported in the Lancet of March 18, 1882, p. 440, Mr. Lister stated that he had been using with still greater satisfaction catgut prepared by soaking it for twelve hours in a one per cent. solution of chromic acid, and then for twelve hours more in sulphurous acid (B. P.). Lastly it is dried, in which state it may be kept, being soaked

Without other application, age alone renders catgut less easily softened by blood-serum.

Immersion of catgut in oil of juniper for twenty-four hours, and its immediate transfer to alcohol, ninety-five per cent strength, in which it should be kept till needed, has been introduced by Kocher, of Berne, as a reliable method of preparing catgut. The gut, thus prepared, is very agreeable to handle, ties nicely, and is not absorbed too soon.

Italian catgut is superior to all others in point of durability and evenness of texture. Harp-strings should be chosen by preference; No. 0 for the finest thread; No. 1 for medium; and No. 2 for the heaviest size.[1]

After a catgut ligature is applied, the ends are to be cut off short, and the wound closed without any further attention being paid to the ligature. When a properly prepared gut is used nothing more is ever seen of the ligature. It is mechanically unirritating and physiologically aseptic, and produces no disturbance in the process of repair by its presence, and is ultimately removed by absorption in the course of the tissue metamorphoses that are incident to the normal life of the tissues in which it is embedded. An indefinite number of ligatures may be applied, according to the demands of speedy and perfect hæmostasis, in a wound without hindering its union by first intention. By its use one of the greatest hinderances to union by first intention has been removed, and the treatment of wounds greatly simplified. The portion of tissue included in the noose of the ligature does not die, nor does the external coat of the included vessel become divided or ulcerate. It is applicable in septic wounds as well as in those that are kept aseptic. It is only a little less easy to manage than silk.

When immersed in carbolic oil it improves with age, so that it is especially adapted to being kept in stock by the general practitioner for occasional use at indefinite intervals.[2]

Threads of *aseptic silk* and of *metal* have been used for ligatures, and with advantage over the ordinary thread on account of their unirritating nature. Their ends having been cut off close, the wound has been closed

---

for a quarter of an hour in a carbolic lotion before being used. Catgut thus prepared, will withstand the action of living tissues for three weeks, and after prolonged steeping in carbolic lotion is as strong as in the dry state.

[1] These can be procured in New York from L. H. Keller & Co., 64 Nassau Street.

[2] The surgeon who does not care to prepare the catgut for himself, can procure it in a very convenient shape, and of reliable quality, ready for use, in various sizes, wound on glass rollers, and kept in carbolic oil, from C. Am Ende, of Hoboken, N. J.

and the union by first intention of the wound secured, while the ligature has become encysted. Such a favorable result, however, experience has shown, cannot be relied upon with any certainty in any given case, so that the use of these agents in this way has fallen into general disfavor, except for purposes of ligating intraperitoneal vessels, in which case a more certain encysting of the thread can be relied upon, owing to the nutritive peculiarities of that membrane.

Silk thread may be made aseptic by boiling it for an hour in a five per cent. solution of carbolic acid, and afterward preserving it for use in a fluid of similar strength; or by soaking it for two hours in a one per cent. solution of corrosive sublimate, and subsequently keeping it in a weaker solution (one-tenth of one per cent.).

Technique of Ligation.—The bleeding vessel must be seized by a suitable pair of forceps and drawn out from the tissues, among which it has

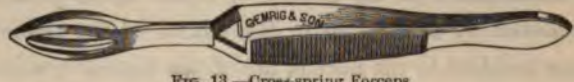


FIG. 13.—Cross-spring Forceps.

retracted, sufficiently to permit it to be isolated and to be encircled by the ligature far enough back from its free end to guard against danger of its slipping off. The hæmostatic forceps (Figs. 10 and 11) will probably have already been applied, and none better could be secured to facilitate the application of the ligature when desirable. It is essential that whatever forceps are used should hold the vessel firmly, and not be liable to become accidentally displaced, and that it should remain closed automatically when once it has been applied. The form shown in Fig. 13, in which the blades cross and are kept shut by their own spring, is an excellent model. The expanded shape of the blades as they near their points facilitates the slipping down of the noose upon the vessel as the thread is tied, and prevents the forceps from being included in the knot.

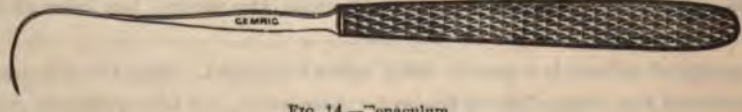


FIG. 14.—Tenaculum.

A *tenaculum* (Fig. 14) may sometimes be used instead of a forceps for picking up a vessel when it is embedded in dense tissues that do not permit its being readily drawn out. The sufficient isolation of the vessel from other structures may be generally effected without trouble; but this

may not be practicable when the tissues have been matted together by previous inflammation, or where the natural density of the tissues pre-

FIG. 15.—Ligation of Vessel in Dense Tissue (*MacCormac*).

FIG. 16.—Ligation *en masse* (*Esmarch*).

vents its being drawn out. Should the vessels be brittle from disease of their coats, it may be best also to tie up with them a cushion of the soft parts. To accomplish this a curved needle, armed with the ligature, may be passed beneath the bleeding point through the tissues so as to include with the vessel a small portion of the adjacent tissue, as in Fig. 15; a ligature thus tied cannot slip, and when catgut is used and the wound is kept aseptic no necrosis of the included portion will take place.

FIG. 17.—The Reef-knot.

FIG. 18.—The Surgeon's Knot.

Fig. 16 will suggest another method of accomplishing the same end. The ligature should be tied in a single reef-knot (Fig 17), in preference

to the surgeon's knot (Fig. 18) or the common granny-knot. It is necessary to use no more force in drawing the knot than is required to firmly and securely close the vessel, which may best be done by placing the index

FIG. 19.—Tightening the Ligature.

fingers upon the thread close to the point of application to the vessel (Fig. 19) and through them making traction.

In ligating the larger arteries the knot should be drawn sufficiently tight to cause the internal and middle coats to give way if the common silk ligature is used; but this is less necessary, though unobjectionable, if the catgut is used. When the catgut or the aseptic silk ligature is used, the ends should be cut off short, and the knot abandoned to itself; when

FIG. 20.

FIG. 21.

FIGS. 20 and 21.—Laceration and Incurvation of Internal Coats of an Artery from External Injury (*Bryant*).
B B, plugs formed by incurved internal coats.

the ordinary thread is used, one end should be clipped off quite close to the knot, and the other brought out of the wound.

MEANS OF PLUGGING THE VESSELS.—These include torsion, coagulants, and the actual cautery.

Torsion.—When the internal and middle coats of an artery are lacerated and separated from the outer coat, the elastic quality of the middle coat causes it to become retracted and incurved, and thus to block up more or less completely the lumen of the vessel. (See Figs. 20 and 21.) Arteries that are torn across, as in lacerated wounds, may be spontaneously closed to such a degree by this cause that no bleeding will take place from them, an entire limb being torn from the body without any hæmorrhage following.

This retraction and incurvation of the inner coats of an artery may be accomplished at will by sharply twisting the cut end of the vessel. The practice of this manœuvre upon a bleeding vessel constitutes "torsion."

The first systematic and intelligent application of torsion as a means of arresting bleeding is to be credited to the French school of surgeons of the early part of the present century, of whom Amussat,[1] Velpeau,[2] and Thierry,[3] nearly at the same time appeared as its advocates, each with a peculiar method of his own. To the elaborate memoir of Amussat, especial mention is due for the manner in which it developed and illustrated the principles on which the practice is to be based. Nevertheless it has never gained general confidence except for the closure of small arteries. More recently, however, it has been warmly advocated by Bryant, of London, who says:[4] "In a physiological point of view there is no method more perfect at command for the control of hæmorrhage than that of torsion; because, unlike acupressure, which uses one only of Nature's hæmostatic processes, or the ligature, which is a foreign body in a wound, and becomes a source of danger by undoing at a later what has been done at an earlier period of the case, it utilizes to the utmost all the physiological processes employed by Nature to prevent and arrest bleeding, and places the vessel in the most favorable position for them to take effect." To continue to quote from the same author (p. 302): "When an artery is closed by what is termed torsion, the inner coats are ruptured (Fig. 22, B and C), and the outer (A), when not twisted off, closed by the twists to which it has been subjected. But the inner coats, instead of being simply

[1] *Séance de l'Académie Royale de Médecine*, July 16, 1829. *Archives Générales de Médecine*, 1829, tome xx., p. 606.

[2] *Journal universal et hebdomadaire de Médecine et de Chirurgie*, etc., 1830, tome i., p. 488.

[3] *De la Torsion des Artères.* 8vo. Paris, 1829.

[4] Practice of Surgery, p. 306. Philadelphia, 1879.

divided in a linear manner, as occurs when the ligature is used, become ruptured, separated from the outer coat and incurved, their divided ends turning into the vessel, and in the most perfect examples forming com-

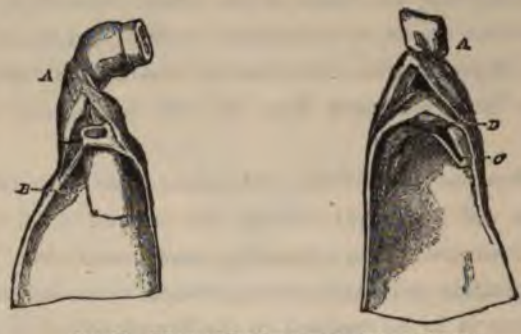


FIG. 22.—Effects of Torsion upon an Artery (*Bryant*).

plete valves, not unlike the semilunar valves of the heart." As to the practical results of torsion, he says (p. 307): "After nine years' experience of the practice among vessels of all sizes (the femoral being the largest), I have had no mishap. I have further observed that wounds have

FIG. 23.—Torsion of Brachial Artery (*Erichsen*).

united more rapidly and kindly—primary union being the rule; there has been less constitutional disturbance after operation, and consequently less liability to traumatic fever, pyæmia, and other complications, such as we

are all too familiar with in the practice of surgery. At Guy's Hospital we have had two hundred consecutive cases of amputation of the thigh, leg, arm, and forearm, in all which the arteries had been twisted (one hundred and ten of them having been of the femoral artery) and no case of secondary hemorrhage."

To apply torsion Amussat recommended that the artery be drawn out for about half an inch by one pair of forceps; that it then be seized at its attached end by another pair of forceps (see Figs. 23 and 24) to steady and

FIG. 24.—Torsion of an Artery (*Esmarch*).

hold it, while with the first pair of forceps the end be twisted off by about a dozen turns. According to Bryant, the vessel need be simply drawn out, as for the application of a ligature, and three or four sharp rotations of the forceps made. In large arteries, such as the femoral, the rotation should be repeated till the sense of resistance has ceased. The ends should not be twisted off. In small arteries the number of rotations is of no importance, and their ends may be twisted off or not, as may be preferred. When the vessels are atheromatous or diseased, fewer rotations of the forceps are required, the inner tunics of the vessel being so brittle as to break up at once and incurve.

Torsion-forceps should have jaws broad enough to grasp the whole width of the vessel which is to be twisted, and their teeth should be blunt, lest they cut through the tissue of the vessel which they grasp.

Forceps after the model shown in Fig. 25, devised by Wight,[1] of Brooklyn, answer better the requirements of torsion than the ordinary artery forceps.

[1] Proceedings of the Medical Society of King's County, 1880, p. 380.

Coagulants.—The introduction into a wound of substances which by their combination with the effused blood shall form a firm tenacious coagulum to act as an efficient plug to the bleeding vessels is to be resorted to only as a last resource, when other methods are inapplicable or inefficient. Such reagents are irritants, the coagula formed act as foreign bodies, and their use destroys any possibility of union by first intention. Whenever used they are to be combined with direct compression, if possible. Wounds involving spongy tissues, and cavities or organs, such as the mouth, nose, and uterus, where it is impracticable to ligate the bleeding

FIG. 25.—Wight's Artery Forceps.

vessels, most frequently call for the application of coagulants. Previous to their application the soft coagula already present should be removed, the bleeding surface should be wiped as dry as possible, and then a compress saturated with the reagent should be firmly pressed to the bottom of the wound directly upon the bleeding orifices. The compress so applied should then, if possible, be secured in place by a bandage. Cavities, from the walls of which hæmorrhage is taking place, should be packed with absorbent plugs saturated with the reagent. Of the multitude of substances that have been used as coagulants but two deserve mention, the subsulphate of iron (Monsel's salt) and alum, both of which are effective antiseptics as well as coagulants.

The subsulphate of iron may be used either in powder or in solution. A compress saturated with a lotion made of the officinal liquor ferri subsulphatis, diluted from four to six times with water, is a powerful hæmostatic, while it is less irritating than the stronger solutions. The iron produces immediately a dense, firm, and tough coagulum, that continues to shrink and harden for some time after its formation.

Alum is less powerful and instantaneous than the iron salt, but its astringent and coagulating effect is great. It may be applied in powder, or in saturated solution. The powder enclosed in gauze, so as to form a small bag, forms an efficient hæmostatic tampon, and is particularly suitable for plugging mucous canals.

The Cautery.—Iron heated to a dull red heat was the potential cautery of the ancients, which alone was relied upon to control arterial hæmor-

rhage. It is still frequently made use of for the control of bleeding from deep-seated vessels, and in the course of operative procedures upon very vascular parts, as the maxillary bones, the tongue, the neck, the uterus, and the rectum. It is not only a coagulant but a caustic, and destroys the tissues to which it is applied, forming a thick eschar, which for a time effectually seals over the entire wound-surface. When it becomes detached as a slough after a few days, hæmorrhage frequently recurs from the ulcerated vessels. Care is to be exercised not to heat the cautery-iron above a dull red heat—the bright red or white hot iron consuming the eschar and leaving the vessels unsealed. In the emergency which calls for the cautery, the ingenuity of the surgeon will extemporize the needed cauting-iron. In the systematic arrangements for the prevention of hæmorrhage by the cautery in the course of surgical operations the ancient cauting-irons, with their furnace and bellows, have given place to the galvano- and thermo-cauteries.

Means of Interrupting the Blood-Current.—The force with which the blood-current shall reach the opening in a severed vessel may be modified by position, by compression of the vessel or its parent trunk between the wound and the heart, and by the internal administration of drugs which lessen the force of the heart's contractions. These means are chiefly available as temporary resources until means of direct permanent hæmostasis can be devised.

Position.—The elevation of the limb, so as to add the force of gravity to the obstacles to be overcome by the blood-current, will materially diminish the force of the arterial supply to the more distant parts of the limb. It promotes also depletion of the veins. It is a resource not to be overlooked in case of wounds of the distal parts of the extremities.

Compression of the Vessel, or its Parent Trunk, between the Wound and the Heart.—This may be accomplished by one or more of the following ways: Forced flexion, digital compression, the tourniquet, the elastic bandage, acupressure, and ligation.

Forced Flexion.—When the forearm is strongly flexed upon the arm, in a muscular person, the brachial artery, in addition to being bent at an acute angle, is compressed both between the biceps and brachialis anticus muscles above, as they contract, and at the angle of flexion by the muscular mass there existing, while below, the first portions of its two main branches are compressed between the contracted muscles of the forearm. Sufficient compression may thus be exerted to completely interrupt the

flow of blood through the arteries, and to make this an efficient means of assisting in the arrest of hæmorrhage from wounds of the distal parts of the upper extremity, and particularly from wounds of the palmar arches.[1]

Flexion of the leg upon the thigh has but a very feeble effect upon the arterial current in the vessels beyond. By placing a compress in the ham and practising flexion a greater interruption can be produced. By strongly extending the foot, its dorsal artery may be compressed under the anterior annular ligament sufficiently to interrupt the current of blood through it.

Digital Compression.—When the bleeding is from a vessel which, either itself or its parent trunk, has in some part of its previous course passed superficially over a bony surface, the pressure of the thumb or fingers may be sufficient to compress it against the bone powerfully enough to completely interrupt the current of blood through it.

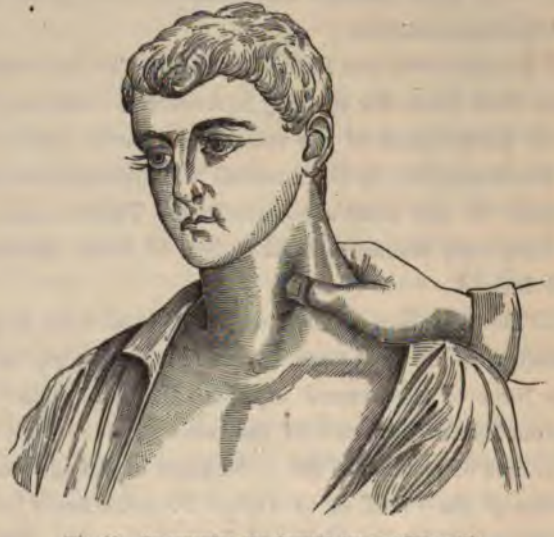


Fig. 26.—Compressing the Carotid Artery (*Esmarch*).

The common carotid artery may thus be compressed against the transverse processes of the cervical vertebræ by the thumb thrust between the larynx and the inner border of the sterno-cleido-mastoid muscle in such a manner as to make pressure downward and inward (Fig. 26). The facial,

[1] Adelmann: *Die gewaltsame Beugung der Extremitäten als Stillungsmittel bei arteriellen Blutungen derselben. Archiv für klinische Chirurgie*, 1869, Band xi., Heft 2.

Puel: *Recherches anatomiques et expérimentales sur le mécanisme de l'hémostase par diverses attitudes particulières des membres. Bulletin et Mémoire de la Société de Chirurgie de Paris*, 1882, tome viii., p. 727.

temporal, supraorbital, and occipital branches are all easily compressed by the finger of one familiar with their positions.

The subclavian artery may be compressed, as it passes over the first rib behind the scalenus anticus muscle, by strong pressure made downward and inward into the fossa behind the clavicle at the outer border of the sterno-cleido-mastoid muscle. The unaided finger is, however, not strong enough to maintain the requisite force. A door-key, with its handle wrapped with cloth, is the classical substitute.

FIG. 27.—Compressing the Brachial Artery (*Esmarch*).

By raising the arm and making pressure along the anterior fold of the axilla, the axillary artery can be compressed against the head of the humerus.

The brachial artery may be easily compressed against the humerus, at the centre of the arm, by pressure made along the inner border of the biceps (Fig. 27).

The radial and ulnar branches are readily compressed in the lower third of the forearm.

The abdominal aorta, when the abdominal walls are relaxed and the intestines empty, particularly in thin subjects, can be compressed against the vertebræ, by pressure applied a little to the left of the middle line at the

level of the umbilicus. The fingers of one hand should be reinforced by those of the other to supply the requisite degree of pressure.

The common iliac artery may be compressed against the brim of the pelvis by the hand introduced into the rectum, or with a lever of wood introduced according to the method of Davy, of London (Fig. 28).

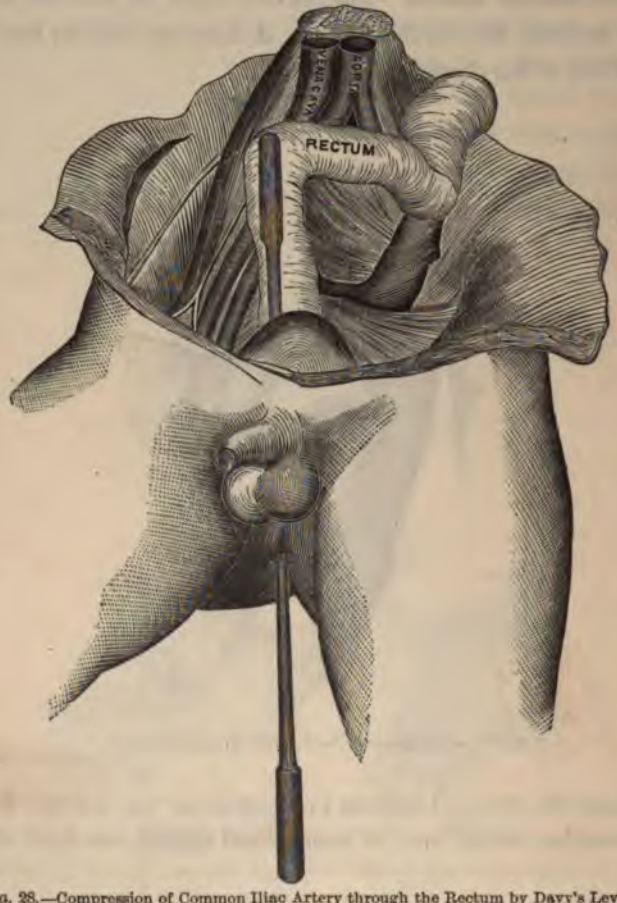


Fig. 28.—Compression of Common Iliac Artery through the Rectum by Davy's Lever.

The femoral artery is most securely compressed, just below Poupart's ligament, against the ileo-pectineal eminence. It should be made with the two thumbs placed the one upon the other (Fig. 29), and the pressure should be made upward and backward beneath the ligament upon the expanse of the eminence. The thickness of the intervening parts makes attempts at compressing the artery against the femur in the middle third of the thigh uncertain.

The posterior tibial at the inner ankle, and the dorsalis pedis upon the dorsum of the foot, are readily compressed by the fingers.

Tourniquets.—Any apparatus by means of which graduated pressure can be made upon a vessel is a tourniquet. The original idea, as the name indicates, involved a twisting or screwing contrivance for graduating the pressure, which is the power employed in the instrument most in use at the present day, the tourniquet of Jean Louis Petit (1674–1760). This

Fig. 29.—Compressing the Femoral Artery (*Esmarch*).

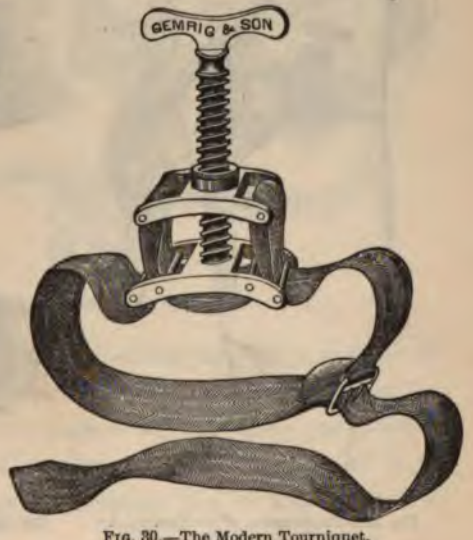


Fig. 30.—The Modern Tourniquet.

instrument (Fig. 30) consists of two metal plates, the distance between which can be regulated by means of a screw, and which are connected by a strong silk or linen strap, which is meant to pass around the limb, and which is fastened by a buckle. In using this instrument the lower plate, underneath which a pad or a roll of bandage has been placed, should be applied exactly over the point corresponding to the artery (Fig. 31); the strap that encircles the limb should then be drawn quite tight, when the screw is turned so as to force the pad down upon the subjacent vessel until it ceases to pulsate. The tourniquet in use before the invention of the instrument of Petit was a simple band encircling the limb tightly,

underneath which a stick was thrust, by the twisting of which powerful compression could be produced. The same method is still often adopted with advantage for improvising a tourniquet in cases of emergency. It is frequently spoken of as the "Spanish windlass." A handkerchief or bandage, or any similar material, to encircle the limb, and a stick, or rod of any kind, to twist it with, being the only essential things for its construction; a knot in the handkerchief or a stone enfolded may serve as a compress to apply directly over the vessel to be compressed (Fig. 32). Another form

FIG. 31.—Compression of the Femoral Artery by Tourniquet (*Agnew*).

FIG. 32.—Improvised Torsion Tourniquet (*Esmarch*).

of improvised tourniquet, applicable to the brachial artery is shown in Fig. 33, in which by means of two sticks, arranged as shown in the figure, powerful pressure by leverage can be exercised on the vessel.

The application of a tourniquet should be discontinued at the earliest possible moment, on account of the pain which it produces, and the interference with the venous circulation of the parts beyond, as the result of which death of more or less of the limb may ensue. It is to be regarded only as a temporary expedient, to be substituted at the earliest practicable moment by other means of direct and permanent hæmostasis.

The Elastic Bandage.—If a piece of india-rubber tubing or bandage (Fig. 34) be wound with strong traction several times round a limb, and the ends be fastened by a knot or clasp, all the soft parts, and with them the

vessels, are so firmly compressed that not a drop of blood can pass through. The facility and certainty with which the blood-current can be interrupted by such an elastic band, has caused it to replace, to a very great extent, all forms of tourniquets, since attention was drawn to its advantages in con-

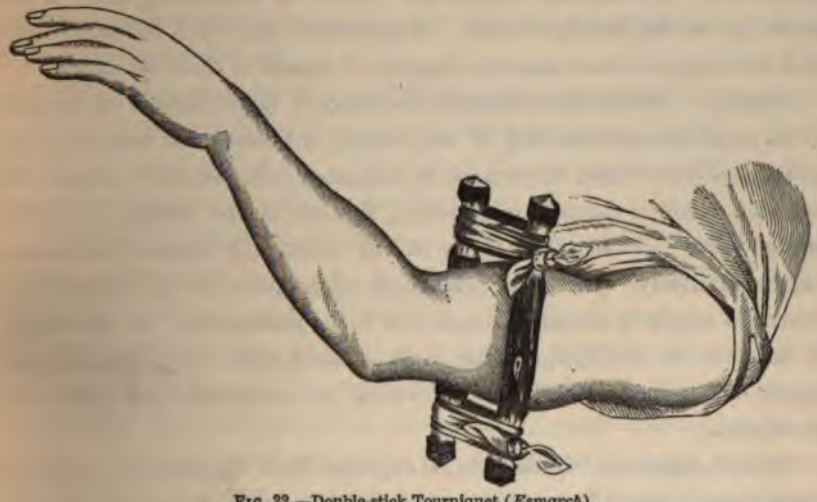


Fig. 33.—Double-stick Tourniquet (*Esmarch*).

nection with the bloodless method of performing surgical operations devised by Esmarch, of Kiel.[1] If an elastic bandage be put (no matter how tightly) only once round a limb, the pressure will not suffice completely to compress the blood-vessels; but if it be bound several times round at the same point, every turn so increases the pressure that in a short time no more blood can pass.

Fig. 34.—Esmarch's Elastic Tube.

Acupressure.—Those methods of acupressure may be used to compress a vessel in its continuity, so as to interrupt the flow of blood through it, in

[1] *Ueber Künstliche Blutleere bei Operationen.* Volkmann's *Sammlung klinische Vorträge*, No. 58.

which, when the tissues are transfixed by the needle they are so put upon the stretch that by their elasticity they press the needle firmly and continuously against the vessel, or in which the needle, having been thrust under the vessel, is made the base against which pressure is made by thread thrown over the included tissues and about the projecting ends of the needle as in the harelip suture. Acupressure may thus be substituted with advantage in some cases for ligation of vessels in their continuity.

Ligation.—When direct ligation of a vessel is impracticable on account of the depth or inaccessibility of the wound, or because the necessary disturbance of the wound, or perhaps its extensive enlargement to expose the bleeding vessel, is deemed inexpedient, ligation of the vessel in its continuity above the wound, or of its parent trunk, will control the hæmorrhage definitively. Whenever permanent interruption of the main supply current to a part is necessary, ligation is to be performed. In the choice of material for the ligature, the same reasons exist for preferring the aseptic catgut cord which have been stated in connection with ligation in the wound.

Cardiac Sedatives.—Little is to be expected from the action of remedies administered internally for the immediate staunching of surgical hæmorrhage, but in the after-treatment they may play a more important rôle, combined with other general means. Gross[1] makes the following observations on the use of such means:

"Whatever mode of procedure be adopted for arresting the bleeding, it is an object of primary importance to place the affected part perfectly at rest, in an easy and elevated position; the slightest motion might be injurious, especially when no ligature has been used, and should, therefore, be sedulously guarded against. Repose of the body is equally necessary with that of the part, and it is hardly needful to add that mental tranquillity is also of the greatest moment. Cardiac action, too, must be maintained in the most perfect quietude, as any perturbing agency of this kind cannot fail to favor a return of the hemorrhage and exhaust the system. With this view a full anodyne should be administered early in the disease, the dose being repeated from time to time so as to sustain the soothing influence of the remedy. Too much stress cannot be laid upon the use of opiates in the management of arterial hæmorrhage, and it is surprising that the remedy is not more generally employed than it seems to be. To allow

[1] System of Surgery, 1882, vol. i., p. 675.

the heart to go riot, or to move and toss about tumultuously, as it is so liable to do after serious loss of blood, while every local precaution is taken for the suppression of the bleeding, is assuredly a strange inconsistency, and one altogether irreconcilable with experience and common sense. When the bleeding proceeds from a great number of small vessels, a restraining influence may be expected from the administration of ergot in full and repeated doses.

"When high constitutional excitement exists, the effect of the anodyne should be aided by the judicious use of aconite or veratrum viride. When the skin is very hot and dry, a full dose of Dover's powder often answers an excellent purpose in calming the heart's action.

"The diet should be perfectly bland, and sufficient in quantity to supply the wants of the body. To give less might cause irritability of the system; to give more, over-stimulation. The drink must be cold and acidulated, and not taken so freely as to oppress the stomach, as it will be sure to do if the quantity is not carefully restricted, as the thirst is always urgent after the loss even of a comparatively small amount of blood. Lumps of ice, or pounded ice, held in the mouth, and gradually swallowed, often prove most grateful and beneficial. The air of the apartment must be kept perfectly cool; in short, every effort must be made to maintain the tranquillity of the circulation."

CHAPTER VII.

THE GENERAL CONDITION OF THE PATIENT.

Shock—*Anæmia*—Auto-transfusion—Transfusion—Direct Transfusion—Defibrination of Blood—Technique of Transfusion—Dangers of Transfusion—Peritoneal Transfusion.

SHOCK.

The lighter degrees of shock quickly and spontaneously disappear; in the more severe cases the indications are for stimulation, free access of air, recumbent posture, warmth, and reassuring words if consciousness is present.

If the patient is able to swallow, brandy or other alcoholic stimulants should be given in small and frequently repeated doses till reaction is assured; if unconscious, these should be injected *per rectum;* if the prostration is extreme, hypodermic injections of brandy, in doses of from one-half to one drachm, or of ether, in doses of from 15 to 30 minims should be administered. Intravenous injections of from 5 to 10 minims of liquor ammoniæ fortior may also be resorted to. Repeat the injections every ten minutes till the patient is able to swallow. If reaction is delayed, tincture of digitalis, in half-drachm doses, every hour, should be substituted.

Heat and friction to the extremities, hot cloths over the heart and stomach, warm blankets to envelop the body are also to be employed.

If the respiration fails, artificial respiration is to be practised.

If the shock is being aggravated or prolonged by the irritation of a mangled limb, or the presence among the tissues of a foreign body, or the continuance of hæmorrhage, immediate operative interference is needed as the less of two evils; in all other cases operation should be deferred until reaction is secured.

As reaction comes on, stimulants are to be replaced by supporting and anodyne measures. Renewed evidences of prostration are again to be met by the use of stimulants.

ANÆMIA.

Should loss of blood have been so great as to cause the want of the blood to be a source of immediate danger, auto-transfusion should first he performed.

Auto-transfusion is done when the blood is forced from the extremities and collected in larger quantities in the vessels of the central organs. It is easy and expeditious of performance, and free from the dangers and difficulties of transfusion, whether of blood or of milk, and offers results scarcely inferior to those of transfusion itself. For its performance, after the hæmorrhage has been stopped, the patient must be placed with his feet higher than his head, in order that the blood may gravitate toward the heart and medulla oblongata; the limbs are then to be bandaged firmly, beginning at their distal portions, preferably with rubber bandages—in default of which, however, ordinary ones may be used—so that the limbs are rendered comparatively bloodless. If the fainting is extreme, complete inversion of the body, holding him up by both feet, is the most efficient method of revivifying the exsanguinated brain, while rhythmical compression of the thorax—artificial respiration—is the best means of stimulating the action of the heart and lungs.

Transfusion.—When the loss of blood has been extreme, and auto-transfusion is inadequate to insure permanent rallying, the injection of a quantity of blood from a healthy person into the veins of the sufferer is demanded. One great advantage of the practice of auto-transfusion is as a temporary expedient to gain time for the necessary preparations to be made for transfusion.

Although transfusion has been practised only as a *dernier ressort* in desperate conditions, the results attained by it which are recorded have been very encouraging. When the operation has been performed for injuries to blood-vessels or for the hæmorrhage resulting from them, the recoveries were fifty-eight per cent.; when performed in consequence of *post-partum* hæmorrhage, the recoveries were fifty-six per cent.[1]

The operation is simple, easy to perform, and with careful attention to certain details, is free from danger. Since it is an operation of emergency, those methods only which are the simplest and demand the least special apparatus are worthy of consideration in connection with it. For its per-

[1] Howe: Transfusion of Blood. Annals of the Anatomical and Surgical Society, 1880, vol. ii., p. 164.

fect performance no other apparatus is necessary than a funnel, a flexible tube, and a canula, and, in default of these, an ordinary syringe, if it be clean, and its nozzle be not too large to pass into the opened vein, will suffice.

The objections to the use of the syringe are that the repeated introductions of its nozzle into the vein of the recipient are often difficult and are likely to be attended with undesirable violence to the vein and the adjacent tissues, and that the required manipulations, if prolonged, involve additional dangers of the introduction of clots and of air. Still these are difficulties that can be surmounted by care and skill, and should not be permitted to stand in the way of making an attempt with the syringe if better apparatus is not available.

This book is the property of
COOPER MEDICAL COLLEGE,
SAN FRANCISCO, CAL.
and is not to be removed from the
Library Room by any person or
under any pretext whatever.

FIG. 35.—Apparatus for Transfusion.

When the syringe is to be used, the blood to be injected is allowed to fall into a tumbler or cup that stands in a basin of warm water (100° F.). As soon as about two ounces have been drawn, it is sucked up into the syringe, the nozzle of which is then inserted into the previously exposed vein of the patient, and the contents slowly and cautiously driven in. This is repeated until the required amount of blood has been injected.

If, however, a suitable funnel, tube, and canula (Fig. 35) can be procured, the process of transfusion becomes less difficult and the result much more likely to be satisfactory. The principle upon which the efficiency of such an apparatus depends is that of hydrostatic pressure. The blood from the donor is made to flow directly into the funnel as a receiver, and thence is transmitted through the tube and the canula into the vein of the recipient

(see Fig. 36). By elevating or lowering the funnel the force of the injection is increased or diminished. Such an injection is gradual and continuous, is little likely to be embarrassed by the formation of coagula, and involves the minimum amount of time, of manipulation, and of violence to the vein and its sheath. Previous to inserting the canula in the opened vein, both it and the tube should be filled with warm water, to which a little salt, or five to ten drops of liquor ammoniæ have been added. As the

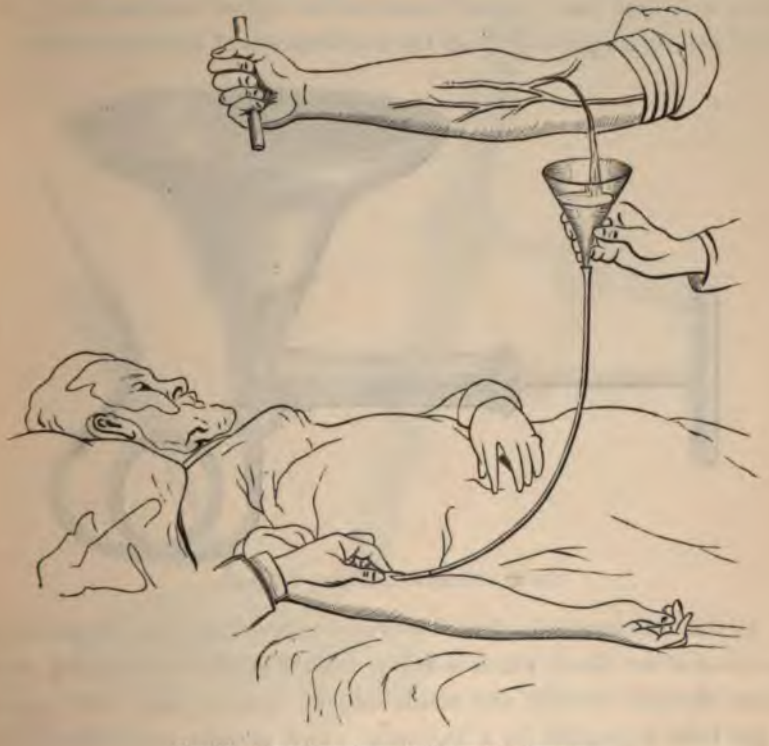


Fig. 36.—Direct Transfusion by Hydrostatic Pressure.

canula is being inserted some of this fluid should be allowed to slowly escape, that all air may with certainty be excluded. The whole apparatus should have been previously warmed by immersion in blood-warm water. This apparatus may be quickly extemporized from materials found in every drug shop. The canula may be made from a bit of glass-tubing, the heat of an alcohol-lamp being sufficient to enable the surgeon to shape it or draw it down to the necessary size.

A canula with a stopcock is a convenience, but even the stopcock may

become a source of embarrassment by introducing an unevenness in the interior of the duct that might determine the formation of coagula in the passing blood-current.

A pinchcock made out of stiff wire, as in Fig. 38, is a desirable accessory when rubber tubing is used, but may readily be replaced by the thumb and finger of an assistant.

Collin, of Paris, has united in one instrument (Fig. 37) a syringe and a funnel, with a flexible tube and canula, which of all the special instruments that have been devised deserves the highest mention for its simplicity and its adaptability to all the requirements of blood-transfusion.

FIG. 37.—Collin's Instrument for Transfusion.

In this instrument the funnel acts as a reservoir for the reception and retention of the blood, which is drawn from it by the syringe, and driven thence through the tube and canula into the recipient vein. The opening to the tube is guarded by a ball-valve, which permits only a heavy fluid, like blood, to enter. The entrance of air is thus guarded against. The air originally in the tube should be first expelled by forcing some of the blood through it, immediately before inserting the canula into the vein. The injection may then be proceeded with, without fear of any air becoming mingled with the fluid injected.

When transfusion is to be performed, a vein is uncovered at the bend of the arm, or above the inner ankle, by a free incision through the overlying skin. When the vein has been clearly exposed, its anterior wall is to be seized by a fine forceps, or a tenaculum, and lifted up, while a trans-

verse incision is made with knife or scissors in the vein, extending through about two-thirds of its wall, so as to make a valvular opening (Fig. 38). While the flap that has been made is still held up by the forceps, the canula is to be introduced. Judgment is necessary in the selection of a canula, that too large a one be not chosen. As a rule, difficulty will be experienced in introducing into the veins mentioned a canula of greater diameter than three or three and a half millimetres. No ligature is neces-

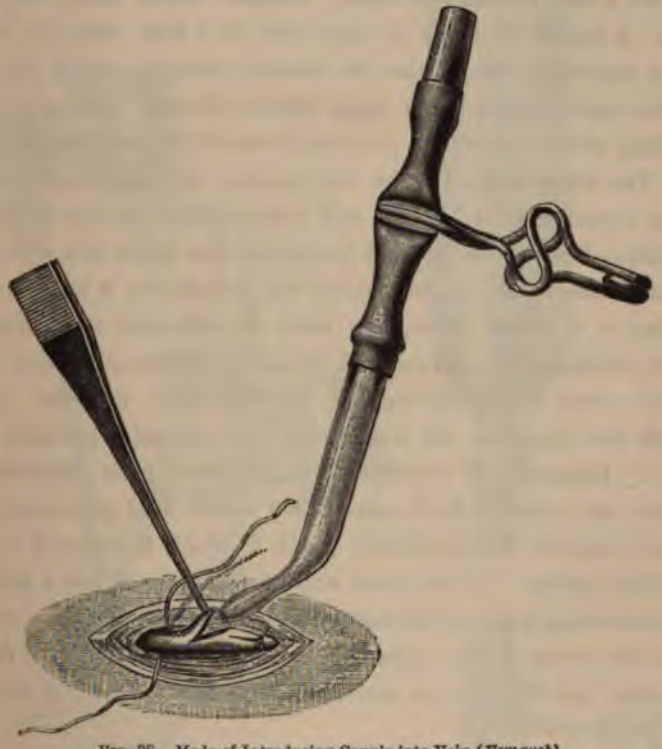


FIG. 38.—Mode of Introducing Canula into Vein (*Esmarch*).

sary to secure the canula. It should simply be held in place by the gentle pressure of the fingers of an assistant, by which also the distal part of the vein should be compressed at the same time.

The blood to be injected should be obtained, if possible, from a young and healthy person, and should be drawn in a full stream from the vein of the donor, thus prolonging the period during which it will remain without tendency to coagulate. To secure this a free opening, at least half an inch in extent, should be made in the vein selected, which will generally be, as for ordinary venesection, either the median, cephalic, or basilic veins.

The blood may be used as drawn, or may be defibrinated before using. Defibrination has as its object the prevention of dangers from coagulation of the blood. It has been established, particularly by the researches of Panum, of Copenhagen, that blood deprived of its fibrine and exposed to the air for some time is not materially deteriorated for restorative purposes. Defibrination is accomplished by drawing the blood into a clean vessel, and whipping it, until deprived of its fibrine, with broom wisps, those from a new broom, thoroughly cleansed before using, only should be used. A bundle of twigs or glass rods, or a fork, may also be used. The fluid remaining should then be strained through a clean, thick linen cloth, then again whipped, and again filtered through clean white satin, the dressing of which has been previously removed by washing in distilled water.[1] The filtered blood flows into a clean, dry glass vessel, which is placed in warm water at 104° F., and remains there till it is required for use. Whipped blood can be kept for twenty-four hours in a well-covered vessel, surrounded with ice, but before the transfusion it must be heated by placing it in warm water, and must be saturated with oxygen by repeatedly drawing it in and out of a syringe. Defibrinated blood may be transfused either by the syringe or by hydrostatic pressure. Fig. 39 represents the apparatus for transfusing by hydrostatic pressure recommended by Esmarch. It consists of a graduated glass cylinder which holds from ten to twelve fluid ounces (300 to 400 fluid grammes), ending below in a rounded and perforated point, to which is fastened a foot of india-rubber tubing. In the lower end of the latter is put a small perforated connecting piece of vulcanite, which accurately fits the connecting piece of the canule. The calibre of these parts must all be of the same diameter, so that there is no interruption in the interior of the entire tube (Fig. 40).

Into this cylinder is poured the defibrinated blood; as soon as it flows out of the tube it is closed immediately above the end-piece by a clip. All the air is removed from the tube by pressing and squeezing in an upward direction. To prevent the blood from becoming cool, the hand which holds the cylinder can press against its outer surface a rubber bag filled with hot water, as in Fig. 39, or cloths wrung out in hot water.

The end of the tube is then attached to the connecting piece of the canule, which has been meanwhile introduced into a suitable vein after

[1] Esmarch: The Surgeon's Handbook, 1878, p. 166.

having been completely filled with the defibrinated blood, or a warm saline solution. The attachment having been made, the glass cylinder is raised with one hand, the patient's arm with the other, both clips are re-

Fig. 39.—Transfusion of Defibrinated Blood by Hydrostatic Pressure (*Esmarch*).

Fig. 40.—Esmarch's Cylinder and Tube for Transfusion of Defibrinated Blood.

moved, and the column of blood is seen to sink slowly in the cylinder (Fig. 39). As soon as the cylinder is nearly empty, the tube is compressed with the thumb and finger, and the canule is withdrawn from the vein, which is then dressed.

The chief objection to defibrinating the blood is the time occupied in the necessary manipulations. When the emergency calling for transfusion is not urgent, such an objection does not hold. When, however, instant action is necessary, the immediate use of the blood, as it flows from the donor's arm, is imperative.

The dangers of transfusion are: 1, embarrassing the enfeebled heart by too rapid a supply of new fluid; 2, the injection of clots that may form emboli; 3, the entrance of air.

The first danger is to be obviated by introducing the new blood very slowly, and by guarding against the transfusion of too great a quantity. Experience has shown that the restorative effects of from six to eight ounces of new blood are fully as marked as when a larger quantity is

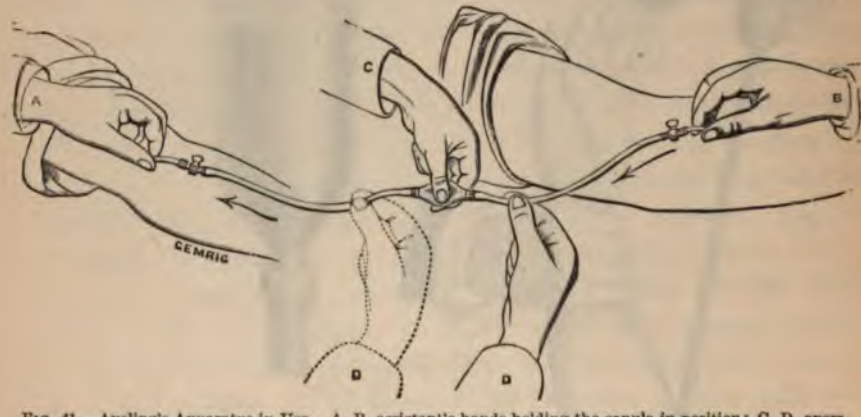


FIG. 41.—Aveling's Apparatus in Use. A, B, assistant's hands holding the canula in position; C, D, operator's hands compressing the bulb, and, alternately, the afferent and efferent tubes.

transfused. For the purpose of transmitting the blood in a more even and gradual manner to the heart, the method of injection into an artery, as the radial or posterior tibial, in the direction of the arterial current, has been practised (Hueter).

To obviate the second danger, the interior of the tubes through which the blood passes in the process of transfusion, should be as free as possible from irregularities, such as projecting shoulders, abrupt turns, and stop-cocks; the injection should be made instantly, and in a regular and continuous flow from its beginning to its end. When time allows, defibrination of the blood may be practised.

The third danger needs only to be kept in mind to secure the necessary cautions in the manipulations of the injecting apparatus to exclude the air.

Numerous instruments other than those here recommended have been devised from time to time. The original apparatus of Lower (1666) was for direct transfusion from vein to vein, by means of silver canulæ that were connected together by a flexible tube made from the carotid artery of a horse or ox. Aveling's instrument (Fig. 41) is essentially the same thing, substituting a rubber tube, expanded at one point into a bulb, for the ox's artery used by Lower. Theoretically the direct transfusion of blood from the vein of the donor to that of the recipient is a more perfect operation than the indirect method by syringe or hydrostatic pressure. Practically, however, the latter method gives equally good results, while it is more easily and certainly accomplished, and places the amount and rapidity of the new blood supply under the full control of the surgeon.

Peritoneal Transfusion.—The method of transfusion (so called) by pouring defibrinated blood into the peritoneal cavity through a canula, rubber tube, and funnel, proposed by Ponfinck,[1] though possibly a valuable therapeutical measure in cases of anæmia of a chronic nature, cannot take the place of intra-venous transfusion in cases of acute anæmia from rapid and excessive loss of blood.

---

[1] *Ueber ein einfaches Verfahren der Transfusion beim Menschen. Wien Medizinische Blatter*, 1879, ii., p. 846.

CHAPTER VIII.

THE CLEANSING OF THE WOUND.

Hæmostasis—*Sponging*—Purification of Sponges—*Irrigation*—Continuous Submersion—Irrigating Fluids—*Drainage*—Natural Drainage—Artificial Drainage—Drainage Tubes—Absorbable Tubes of Neuber, of Macewen—Capillary Drainage—Catgut Drains—Horsehair Drains—Spun-Glass Drains—*General Considerations as to Artificial Drains*—*Résumé*—Primary Drainage—Secondary Drainage—*Accessory Means of Wound Cleanliness*—Adjacent Skin—The Surgeon and his Assistants—Instruments and Appliances—Compresses and Protective Appliances—Purification of the Air—Spray Producers—*Cleansing Septic Wounds*—Curettes—Disinfecting Lotions.

After hæmorrhage shall have been arrested, and the general condition of the patient shall have received the attention which it may have required, the next duty of the surgeon is to proceed to the cleansing of the wound. A full appreciation of the extent of the requirements of wound-cleanliness, and of the minute precautions necessary for their fulfilment, is of the utmost importance in determining the future course of a wound. What these requirements are have been discussed in the chapter in the first section on Wound-Cleanliness. They should have a controlling influence in the choice of measures of hæmostasis. For it is important in securing final hæmostasis that those means only be used which do not themselves violate the rule of cleanliness. The first, and one of the most important, elements of cleansing a wound, indeed—with the exceptions noted in Chapter IV.—is the perfect arrest of bleeding and the careful removal of effused blood. The masses of hardened coagula which styptics leave behind in a wound, preventing union and speedily becoming irritants, make their use a violation of cleanliness, and therefore require their rejection. Exposure to the air and compression alone, or compression with the addition of hot iodized lotions, should be relied on to check capillary oozing. For controlling bleeding from the larger vessels, unirritating ligatures,

whose ends can be cut off, and the ligature itself be left to be absorbed or encysted, should be used whenever possible. In default of such ligatures, torsion, forcipressure, and acupressure may be resorted to, by preference, in the order named. The use of the ordinary silken ligature is a violation of every principle of wound-cleanliness, and its employment is to be advocated only when, in the absence of other agents, the immediate necessity for its use outweighs its later disadvantages. In the further prosecution of the primary cleansing of the wound, search is to be made for whatever foreign bodies or particles—sand, dirt, fragments of bone, pieces of clothing, of wood, of glass, of metal, etc.—may have been left in the wound. These must, if possible, be removed before the wound is closed. Foreign bodies of some size may most readily be removed by the fingers or by forceps, but the more minute particles, as well as the effused blood, and the wound-secretions, require the use of careful and gentle sponging, or free irrigation.

Both in the primary cleansing of the wound and in the after-dressings, a cardinal principle to be observed is to abstain from all unnecessary disturbance of the wound-surfaces. Minute care in accomplishing primary cleansing will make much more simple the after-cares. The dressing of the wound should be so managed that its self-cleansing should be continuous until healing is complete, and all squeezing and mopping and forcible syringing should be unnecessary.

SPONGING.

The sponge that is to be used upon a wounded surface should be of fine texture, open cells, and sufficiently elastic to expand readily in the hand after water has been expressed from it. The whiteness is a matter of little amount, unless the bleaching has been carried so far as to destroy its texture. It must be soft and pure. Attention to the character of the sponges used is one of the minor details of wound-treatment, which may, however, make the difference between success or disaster in the result. The sponges that are to be obtained ordinarily from druggists in this country have undergone no preparation after their importation. Even the finer qualities of Turkey sponge that are sold for surgical uses still contain much sand, bits of coral and small shells, and some organic impurities. Before they are used, the sand and particles of coral and of shells that may be lodged in their interstices should be removed, first by a thorough beating while the sponge is dry, and then by prolonged and repeated washings in tepid water—hot water shrivels a sponge and spoils it—until

the water comes off clear and free from sand. After they have dried, it will be found that a new beating will still dislodge some sand. As soon as the sponges are sufficiently freed from sand, they should be placed in a solution of permanganate of potassa, 1 to 500, for twenty-four hours. Then they are again washed in clear water, and placed in a one per cent. solution of hyposulphite of soda, to which is added one-fifth the amount of an eight per cent. solution of hydrochloric acid (fort.). The sponges should remain in this solution only for a few minutes, until (in about one-quarter of an hour) they have become white, being constantly stirred with a wooden rod while in the solution.

It will not be well to let them remain too long in this bath, because their substance will become injured so that they will lose their elasticity and easily tear. Lastly, they are again washed until they are entirely scentless, requiring frequent changes in water during two or three days, and immersed in a five per cent. solution of carbolic acid for at least fourteen days before being used.

After having been used they should be thoroughly purified before being again used. For this purpose, after having been washed in water, they should be repeatedly washed in a solution of carbonate of soda—common washing soda—one ounce to the quart of water, to remove any blood or matter, then with water again, and then immersed as before in the five per cent. carbolic acid solution.

In process of time, a sponge, after frequent using, will become so clogged with fibrine, that cannot be washed out, that it is useless. In such cases the sponges may be allowed to macerate in ordinary water for a week or two, until the putrefaction of the fibrine has softened it so that it is easily washed out. Cleansing and immersion of the sponge in five per cent. carbolic acid solution, as before, will again fit such sponges to be used.

When sponges have been used upon surfaces manifestly impure, or about wounds to which any suspicion of infection attaches, they should be steeped for five minutes, after the preliminary washing, in liquor sodæ chlorinatæ, diluted with an equal part of water. A longer steeping endangers the destruction of the sponge itself by the chlorine.

By the use of these measures for purifying sponges, they may be used repeatedly and for an indefinite time. Without these precautions, the repeated use of a sponge is fraught with danger, as it may be the bearer of infection from one wound to another.

Whenever a soft sponge whose purity can be relied on is not accessi-

ble, the cleansing of a wound should be attempted by some substitute for it, rather than by using a sponge of doubtful character. Pieces of cotton cloth, old, soft, and absorbent, made clean and pure at the time of using, may be made to do good service as substitutes for sponges, and are nearly always available. Dossils of absorbent cotton—cotton from which all gross impurities and fatty matter have been removed, and which is now abundantly supplied by various makers in this country—make almost a perfect substitute for sponges. They may be wrung out in any antiseptic liquid before using, and, being thrown away as fast as used, are not liable to violate cleanliness by a second use.

IRRIGATION.

The passage of a gently flowing stream of water over the wound-surfaces, or through its cavities and sinuses, if such exist, constitutes irrigation. It is especially adapted for cleansing the wound of fluids, and light foreign matter, and loose bits of tissue of any kind. No complicated apparatus is necessary for obtaining irrigation. The stream that may be squeezed from a sponge, or poured from a basin or pitcher, may often answer every purpose. The stream produced by a syringe is objectionable on account of its fitfulness and the uncertainty of the force with which it may strike the wound-surfaces. The application of the fountain principle, whenever possible, furnishes the most perfect stream for irrigation. Whenever a bit of rubber tubing, and a utensil that will hold water can be had, as a reservoir, a fountain stream is possible. If from the bottom of the reservoir a tube project, upon which the rubber tubing can be slipped, it will be convenient; but if not, if the rubber tube be passed over the top of the reservoir, and be made into a siphon, it will answer just as good a purpose. By elevating and lowering the reservoir, the force of the stream can be perfectly graduated, according to the will and judgment of the surgeon; by replenishing the supply of fluid in the reservoir, as needed, the time through which the irrigation shall be continued may be indefinitely prolonged.

In the after-progress of the wound, if union by first intention be not secured, recourse to irrigation for the purpose of cleansing it of retained secretions, and of sloughing *débris*, may be necessary. In this respect it largely supplements drainage, and the measure of its frequency and importance is the measure of the imperfection of the provisions for drainage. The aim should be, in all cases, first, by irrigation to remove all foreign, or dead, or waste products from a wound; and second, by drainage to pre-

vent their reaccumulation. Whenever adequate drainage has been impracticable, continuous irrigation might become of value in preventing accumulation of noxious substances. The temperature of the water used for irrigation should always be equal to that of the blood, for a lower temperature exerts a depressing influence on the reparative energy of the wound.

Continuous submersion in warm and hot water is a form of irrigation, and its favorable effect, when experienced, is due to the cleansing of the wound which it accomplishes, as well as to its influence in promoting resolution of inflammatory complications. The value of such submersion in the treatment, especially of lacerated and contused wounds of the extremities, has been warmly praised in this country by Drs. Frank H. Hamilton [1] and David Prince.[2] Dr. Hamilton states that "no treatment hitherto adopted, under his observation, has been attended with equally favorable results. Under this plan the area of acute inflammation is exceedingly limited; erysipelatous inflammation has been almost uniformly arrested or restrained, when it has actually commenced, and it has never originated after submersion; gangrene has, in no instance, extended beyond the parts originally injured, and when progressing, it has, in most cases, been speedily arrested. Septicæmia and pyæmia have not ensued in any case in which submersion has been practised from the first day of the accident. Purulent infiltrations and consecutive abscesses have been infrequent, and always limited to the neighborhood of the parts injured, and of small extent. Traumatic fever, usually present after grave accidents, when other plans of treatment have been pursued, as early as the third or fourth day, has seldom been present when this plan has been adopted, and in no case has the fever been intense or alarming." The favorable effect of submersion upon the progress of a wound, as described by Dr. Hamilton, according to my experience, will not be obtained when the character of the wound is such that all its recesses are not freely accessible to the water, and when the escape of the wound-discharges is impeded. It is the diluting and cleansing function of the continuous irrigation that it accomplishes to which is due, in great measure, the favorable results obtained; thus the hot water, though a carrier of septic germs, and itself favoring the processes of fermentation, yet, by its agency in removing the necessary pabulum for the development of the ferment, and by diluting and washing away at

[1] The Medical Record, 1874, p. 249.

[2] Annals of Anatomy and Surgery, 1882, vol. v., p. 116.

once the noxious products of whatever fermentation does occur, is successful in preventing wound-disturbances. As accessory to this antiseptic influence, there should not be overlooked, in estimating the *rationale* of the benefits to be derived from this mode of treatment, the favorable effect upon the nutrition of the immersed part, which the warmth and protection of the hot-water bath exert.

In consequence of the favorable results obtained by the use of immersion in warm water, reported by Langenbeck,[1] of Berlin, in 1855, and by Zeis,[2] of Dresden, in 1856, this method of wound-treatment was for many years extensively used in Germany, but it has now become largely replaced in that country by more perfect antiseptic methods.

Irrigating Fluids.—Since ordinary water is a common vehicle for septic germs, that which is to be used for irrigating wounds must be sterilized by adding to it some antiseptic in sufficient strength to destroy any germ-life that may chance to be in it. Of the various antiseptics those that will be found most generally available and reliable for this purpose are corrosive sublimate in the proportion of 1 part to 2,500 of water; permanganate of potash, 1 to 100; carbolic acid, 1 to 40, and tincture of iodine, 1 to 40.

DRAINAGE.

Cleansing of the wound is finally completed by providing means to prevent the recurrence in the wound of conditions of wound-contamination. Of these, the first, and most important, is the establishment of a free, short, and direct channel, through which the wound-secretions may freely and continuously flow away. The application of the term "drainage" to this portion of the management of a wound is happily appropriate, for the same physical problem is present for solution as that encountered by the farmer who desires to rid his land of undue and hurtful moisture. His ditches, canals, and drains, find their counterpart in the devices adopted by the surgeon to rid wound-cavities of accumulating secretions.

The provisions for drainage may be divided into *natural* and *artificial*. By natural being meant whatever arrangement or dressing of the wound shall favor the escape of secretions, apart from the insertion of any apparatus as means of conduction; by artificial being meant such tubes, setons, or tents, as may be necessary to supplement or replace natural means.

Natural Drainage may be secured in many instances. In wounds in

[1] *Deutsche Klinik*, 1855, No. 37. [2] *Deutsche Klinik*, October, 1856.

which good coaptation of the surfaces has been possible, and yet in which reasons exist for expecting the production of much secretion, the escape of such secretion may often be sufficiently provided for by leaving open the most dependent portion of the wound. In other wounds in which secretions have accumulated so as to produce tension, by cutting one or more sutures sufficient gaping of the wound may be permitted to answer the needs of drainage. In yet others, the cutting of all stitches, and the unrestricted separation of the entire wound-borders may be deemed best. The "open" method of treating wounds, which has been proven to possess great merits in many instances, is a method in which thorough natural drainage is provided for, and to this unquestionably a large share of the benefits derived from the method are due. The results of different forms of the "open" treatment show that the chief thing of importance in its management is that free escape of secretions be not prevented. For the purpose of securing this free escape wounds are to be enlarged by free incisions, and counter-openings made whenever required. A form of modified open treatment has recently been practised and advocated by Professor Kocher,[1] of Berne, which he calls the method by "secondary suture," in which natural drainage is resorted to for the removal of the bloody and serous oozing that occurs during the first twelve to twenty-four hours after the occurrence of a wound, by leaving the wound open during that period, septic infection being prevented by the use of a bismuth lotion; when the farther secretion has in great measure been arrested, the surfaces are brought together and sutured, without any necessity for further drainage. All wounds which admit of union by first intention, Professor Kocher recommends to be subjected to this method of treatment to avoid recourse to artificial drainage.

Artificial Drainage includes all methods in which foreign substances are introduced into a wound for the purpose of conducting away its discharges. These substances may act by capillarity, serving to keep the wound-surfaces apart, and permitting the outflow of liquid to take place along the interstices between their strands, or may provide tubes through which a free flow is secured. The use of various artificial means for drainage is among the ancient resources of surgery. Guy de Chauliac (1300–1370) taught that it was necessary to place tents and setons "in wounds which you would enlarge, cleanse, or from the bottom of which you would

[1] *Ueber die einfachsten Mittel zur Erzielung einer Wundheilung durch Verklebung ohne Darmröhren.* Volkmann's *Sammlung klinischer Vorträge*, No. 224.

withdraw anything, as in deep wounds which have need of counter-openings, because of the liquor or the liquid excretion which gathers at the bottom and in its recesses." One can also make use, he says, "of a tube of brass or of beaten silver that the ordure may escape from it and not be retained."

But not until within the present generation has the full importance of artificial means of drainage been demonstrated and its practice been systematized. With the systematic practice of drainage the name of Chassaignac is associated, whose researches were published, in 1859, in a work entitled, *Traité pratique de la suppuration et du drainage.* His method consisted in traversing from top to bottom all purulent collections with vulcanized rubber tubes pierced with holes along their sides. He demonstrated and fixed in surgical practice the importance of preventing the retention of pus, and introduced a perfect method of drainage for purulent secretions.

Tubular Drainage.—Pus cannot be removed by capillary drains; its thickness and tenacity prevent its escape through such channels; a tube of some kind or other must be used to secure its escape. The india-rubber tubes introduced by Chassaignac, being flexible, unirritating, easy to manipulate, nearly always attainable, and cheap, continue to be regarded as the most universally applicable means of drainage. These tubes may be obtained of varying diameters, from one-eighth of an inch upward, and of any length. The original tubes of Chassaignac were made of black rubber, which has been considered objectionable from the liability of the free sulphur contained in them to generate sulphuretted hydrogen, and thus to produce disagreeable smells. This objection has been obviated by substituting red rubber for the black rubber in making the tubes. When they are to be used for drainage purposes lateral openings should be made in them at short intervals, the diameter of each hole being about one-third of the circumference of the tube. These openings can be readily made as needed, by simply bending the tube sharply on itself and snipping off one of the projecting corners at the bend with a pair of scissors. (See Fig. 42.)

Tubes of metal, as silver, aluminium, or tin, and tubes of glass may be substituted for the rubber tubes, when the compressible and flexible nature of the latter is liable to be the occasion of their obstruction by their becoming bent, or from the pressure of the tissues through which they pass, or of the dressings that may be applied.

A drainage tube, of whatever substance composed, is a foreign body, and as long as it remains in a wound is liable to provoke disturbance.

They should therefore be removed as soon as the period of profuse secretion, which has made their original use necessary, has passed away, or as soon as the cavity which they were intended to drain has become obliterated. In incised wounds, a tube should not be used at all when the two surfaces can be brought accurately together and maintained in apposition. It is only when care in adjustment, and the use of proper means for retention and support and compression prove to be insufficient to secure and maintain accurate adjustment of wound-surfaces that the use of a tube is indicated.

FIG. 42.—Ordinary Drainage Tube.

The necessity for the removal of the tube, or its readjustment, if its continued use is indicated, may be a source of disturbance to the progress of the wound, and, in any event, as long as it remains in the wound, more frequent dressing of the wound, with its attendant dangers and disadvantages, is necessitated.

For this reason a means of drainage which should afford free escape for secretions during the first days, during which they are most copiously produced, and which should then spontaneously melt away and be absorbed is a desideratum. Such a drainage tube would bring into the treatment of wounds an advantage second only to that already gained in the substitution of absorbable ligatures for the irritating threads that demanded a condition of ulceration and suppuration to accomplish their removal.

Absorbable tubes, made of decalcified bone, have been devised by Dr. Neuber,[1] of Kiel, and used by him as substitutes for the ordinary tubes in the primary dressing of wounds. These tubes are prepared from sound

[1] *Ein Antiseptischer Dauerverband nach gründlicher Blutstillung. Archiv für Klinische Chirurgie*, xxiv., Heft 2; and xxv., Heft 1.

ox or horse bone, or ivory, by turning out of them, in a lathe, cylinders of proper sizes and lengths, and converting these into tubes by drilling holes through them. They are then placed in a mixture of one part of hydrochloric acid and two parts of water. After ten hours' immersion the earthy matter will have almost completely dissolved away, and the tubes, after being washed of the superfluous acid in five per cent. carbolic solution, are ready for use. Such tubes are absorbed just as catgut is absorbed or replaced. According to Neuber, in six or seven days the drain will have become soft and pulpy, and filled with lymph. After ten days all traces of it have disappeared, except whatever portion may have projected outside, which will be found lying detached like a small ring and quite unchanged.

Doctor William Macewen, of Glasgow, has demonstrated the value of the hollow femora and tibiæ of domestic fowls, as substitutes for the expensive tubes drilled out of bone, according to the method of Neuber. His method of preparation is as follows:[1] The tibiæ and femora are scraped—bones from fowls which have been cooked for the table being used—and steeped in hydrochloric acid and water (1 to 5) until they are soft. Their articular extremities are then snipped off with a pair of scissors; the endosteum is raised at one end, and pushed through to the other extremity, along with its contents. They are then reintroduced into a fresh solution of the same strength, until they are rendered a little more pliable and soft than what is ultimately required (as they afterward harden a little by steeping in the carbolized solution). When thus prepared, they are placed in a solution of carbolic acid in glycerine—1 to 10. They may be used at the end of a fortnight from the time of introduction into the glycerine solution. Holes may be drilled in them, or clipped out with scissors. Tubes thus formed are semi-transparent, pliable, and elastic, capable of retaining for some time their form under the weight of thick flaps.

The average duration of the chicken-bone tubes, out of one hundred carefully recorded observations, was something over eight days.

In using them, Macewen directs that they should always be threaded with horse-hair to prevent their being blocked by blood-clot, and to help in maintaining the calibre of the tube patent during the first few days, especially where the dressings might exercise pressure. After the first few days

[1] The Drainage of Wounds. British Medical Journal, February 5, 1881, p. 186.

the hairs, being no longer of use, are to be removed, and the tube left perfectly patent. A similar practice of threading the tube with hair when it is to be inserted into a recent wound commends itself for adoption with any kind of tube. The blocking up of a tube with blood-clot is an accident apt to occur, in which case surgeons have been in the habit of removing the tubes, cleaning them of clot, and reintroducing them. But as the reintroduction irritates the wound, and, at times, provokes fresh bleeding, it is to be deprecated. This may be obviated by threading them with hair, as described, which may be removed as soon as the danger of clot-formation has passed.

Certain important practical difficulties, which have been found to oppose themselves as obstacles to the realization of the ideal advantage expected to be derived from these bone drains of Neuber and Macewen, must be noted. They are likely to suffer untimely collapse, and cease to act as drains from lack of sufficient hardness of their walls when immersed in the wound-secretions. The expedient of forestalling this accident by stuffing them with horse-hair to keep them patent is simply the substitution of a non-absorbable drain, and defeats the special object—infrequency of dressing—which the bone drains are devised to answer. Again, when not too soft, they may become absorbed before the necessity for drainage is over, and by their disappearance determine retention of secretions. This particularly is liable to occur in wounds which have not been preserved aseptic, and those in which the discharge is profuse—conditions in which, especially, perfect freedom of drainage is important. Lastly, if the drain should happen to become surrounded by a coagulum or by devitalized tissue its absorption would be indefinitely delayed. These uncertainties in the behavior of bone drains have prevented their use from becoming general.

Capillary Drainage.—The thin bloody serum, which constitutes the primary secretion poured out from a wound, is capable of conduction to the surface by agents that exert upon it a capillary attraction. For such a purpose those agents only are to be used which are unirritating, comparatively non-absorbent, and sufficiently fine in texture that the interspaces formed when they are made into bundles shall be minute enough to exert well-marked capillary attraction.

Catgut, as a means of drainage by capillarity, was introduced by Professor Chiene, of Edinburgh, who used for the purpose very fine catgut. His manner of using it, as described by Cheyne, in his work on Antiseptic

Surgery, is to take a skein of catgut, containing say twenty threads, and tie it at its middle by a single thread of the same gut. One end of this thread is passed through a needle (Fig. 43), and by means of this the centre of the skein is stitched to the deepest part of the wound. The skein is now broken up into bundles of five or six threads each. One bundle comes out at each angle of the incision, and the other bundles at intervals between the stitches. (Fig. 44.)

FIG. 43.

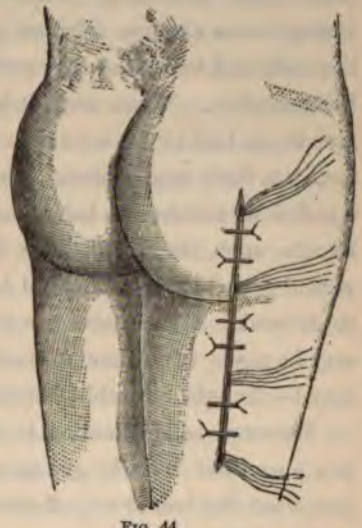


FIG. 44.

FIG. 43.—Catgut Drain ready for insertion (*Cheyne*).

FIG. 44.—Capillary Wound Drainage by Catgut (*Cheyne*). The bunches of catgut coming out at intervals between the stitches. (The wound exaggerated and the threads of catgut separated, in order to show the method more clearly.) The threads of catgut ought to lie in close apposition, for it is the intervals between the threads which act as capillary tubes.

By distributing the threads over various parts of the wound the true principle of drainage is carried out; for, as pointed out by Professor Chiene, in draining a field one does not have one large drain going from one end of the field to another; on the contrary, the field is traversed by numerous small drains. And so in this method we have a number of small drains traversing the wound in several directions.

The catgut drain is an absorbable drain, and is exposed to objections similar to those found to attend the absorbable tubular drains. Drainage might be needed for a longer period than the few days during which the catgut strands could serve as a drain. It swells rapidly after being put in, and becomes less efficient as a drain. If found inefficient, and its removal is desired before it is absorbed, it is likely to have become so closely con-

nected with the neighboring tissues that undesirable violence to them is inflicted by its withdrawal.

Horse-hair presents itself as an excellent agent for capillary drainage. It is always available, and is unirritating and non-absorbent. The fineness of its threads make the bundles made of it capable of exerting a strong attractive force on serous secretions. The credit of its suggestion, as a drain in the treatment of wounds, is given to Mr. White, of the Nottingham General Infirmary. Before being used, the hair should be thoroughly washed in an alkaline solution, to purify it of all foreign matter that may have adhered to it, and afterwards preserved in a five per cent. watery carbolic solution. When used, it is made into bundles of varying size, which are simply laid in the wound in situations most suitable for drainage. To facilitate their management, MacCormac gives the practical hint to choose a sufficient number of hairs, according to the number needed, double the bundle upon itself, and after fastening them together by a single hair wound round them in a spiral form, introduce the convex looped end into the wound. A successive removal of some of the hairs from the bundle may be made from time to time, as a diminution of the size of the drain may be thought desirable, before it is finally withdrawn.

Macewen calls attention to the increased efficiency that may be given to a horse-hair drain by giving to it a syphon action. He is of the opinion that when the hair is cut off close to the lips of the wound, when these are at a higher level than the interior, so that the fluid will require to mount up, it acts feebly as a drain. By leaving the portion on the outside of the wound longer than that which remains in the interior the wisp of hair may easily be formed into a syphon. The syphonage is inaugurated by dipping the wisp into a weak carbolized solution before introducing it, and surrounding it with moistened gauze. The hairs should be tied together at their outer extremity also when syphonage is desired.

Spun Glass.—Dr. Herman Kümmell,[1] of the Hamburg General Hospital, has called attention to the superiority displayed by spun glass, as a material for capillary drainage, over any other substance. This material consists of glass drawn out into threads of great tenuity, which are perfectly flexible and elastic, and feel to the touch soft and smooth like fine wool or silk. They are susceptible of being woven into textile fabrics like vegetable and animal fibres, and can be obtained in the shops in strands, even

[1] *Ueber eine neue Verbandmethode*, etc. *Archiv für Klinische Chirurgie*, xxviii., Heft 3, pp. 689–692.

ten feet in length. The author advises that the drains be formed by braiding together three strands, each of suitable thickness, and that they be kept ready for use in a one per cent. solution of corrosive sublimate. The smallest-sized drain should be about the thickness of a match, it being undesirable to have any greater bulk than is required to carry on the needed capillary flow.

With these glass braids, drainage can be insured to a greater distance without danger from retention, nor is it necessary to shorten them by degrees, as with rubber tubes. They take up but little space, and being flat, separate the tissues to a minimum amount. They produce less irritation than other substances, never provoke suppuration, and when they are removed immediate adhesion of the tissue in their track takes place, so that no fistulæ remain behind. They cannot kink, however great the compression, and never clog. Incisions and counter-incisions to facilitate drainage are unnecessary when these are used, for the capillary attraction exerted by them acts as strongly vertically as when assisted by gravitation. Pus, blood, and fluids containing much blood, are not removable by these drains any more than by other capillary drains. The prolonged residence of these drains in the tissues is attended with the disadvantage only which arises from the firmness with which they may become grasped by the granulation tissue which may insinuate itself into its interstices. Kümmell is in the habit of leaving the first dressing undisturbed for seven days, except in operations of special gravity, in which he changes his dressing on the fourth or fifth day. In one case in which he left the drain undisturbed for fourteen days he was able to dislodge it only by the aid of a cutting instrument.

General Considerations as to Artificial Drains.—"Drains, of whatever character, should be so placed as to carry the secretions from the deeper parts of the wound, as well as from any irregularity or recess, by the straightest and shortest road practicable to the surface. Many short drains, rather than few and long ones, are to be preferred. They are of the greatest importance during the first forty-eight hours, and in deep, extensive, and irregular wounds. The more powerful the antiseptic solution employed, and the more prolonged its employment, the greater will be the amount of after-secretion, and the greater the necessity for efficient drainage. The first dressing is often soaked with bloody serum in twenty-four hours, or even much earlier. When it is necessary to employ drainage tubes for a considerable time they require periodical shortening, or

must be changed for smaller ones. On the renewal of the dressing they should never be used for the purpose of syringing the wound, so long as it is aseptic. The tube should be large in size, rather than small, placed where it cannot be compressed, and have no elbows. The best time to insert the drains is after the sutures have been introduced, but are not yet drawn tight. Two tubes, side by side, often work very well. The time for their removal depends on the amount of secretion. After four to six days the channel in which the drain lies becomes lined with plastic matter, and will remain open for a short time after its removal; where several drains are present they ought to be taken out, one after the other, after an interval.

"The tubes should vary in size from that of the little finger to that of a quill. The ends may be cut transversely or obliquely, so that they may always terminate flush with the surface, and never project beyond it; any projecting part is pressed on by the dressings, and the other extremity will thus be forced upon and irritate the wound-surface, and the function of the tube is impeded.

"Loops of carbolized silk should be inserted at one end, for the purpose of fastening the tube to the skin. They would otherwise occasionally slip into the wound-cavity, and might become healed over, or they might escape externally."[1]

Résumé.—The two indications to be accomplished by drainage of a wound—to prevent the accumulation of ferment pabulum, and to remove fluids already the subject of ferment changes—mean practically the drainage of serum and the drainage of pus. The first is primary and preventive in its nature, the latter secondary and corrective.

Primary Drainage.—Since the retention of accumulated serum within a wound not only acts as any foreign body to prevent apposition and to disturb healing mechanically, but also is prone to rapidly become a fountain of poison to the wound, as ferment changes take place within it, the problem of its removal becomes a question of primary importance in wound-treatment, and is second to no other involved in the subject of wound-cleanliness. The paramount importance of primary drainage is one of the most prominent points insisted upon by Mr. Lister, to whose teachings and practice its establishment in its proper place in wound-treatment is due in great measure. The use of drains, however, is to be regarded

[1] MacCormac. Antiseptic Surgery.

always as a complication, which, if possible, should be avoided, and to be adopted only when other possible means for limiting the amount of serous exudation and preventing its accumulation must be inefficient. When drains are unavoidable, they should be removed as soon as possible, that is, as soon as the tendency to serous exudation ceases, or the obliteration of the cavity drained by them is accomplished, a period of time varying usually from one to four days.

Secondary Drainage.—The drainage of purulent fluids constitutes what I have chosen to call secondary or corrective drainage. For this purpose capillary drains are inadequate, and tubes must be used if artificial drains are required. This is the form of drainage with which the name of Chassaignac will always be associated. In its use, the tube, of whatever material, must be removed from the wound at each dressing, and washed with a strong antiseptic lotion. If this be not done, portions of decomposing material will remain inside the wound, entangled in the openings of the tube, and will become more and more putrid and noxious. The tubes likewise afford a means for irrigating suppurating cavities with cleansing and antiseptic lotions. The use of frequent irrigations with an antiseptic lotion, combined with tubular drainage and free exposure to the air, has been systematized by Prof. T. M. Markoe, of the New York Hospital, in a method termed by him "through drainage."[1] In this method the wound is caused to be traversed by one or more perforated rubber tubes, the number depending upon the extent and complexity of the wound. When the laceration of the deeper parts bring the wounds near to the integument upon the opposite side of the limb, or at a distance from the original aperture, counter-openings are made and the tube passed through so as to emerge at the new opening. Otherwise the tube is simply passed down to the bottom of the wound and the distal end brought out again at a little distance from the point of entrance. A wounded limb, thus traversed, is suspended from a framework, so that it is raised from the bed, and the free discharge of the drainage from the lower opening is secured. Four times a day a solution of one-fortieth carbolic acid is thrown through the drainage tube with an ordinary syringe, and continued until the fluid discharged at the lower opening is perfectly clear. The penetration of this fluid to all the recesses of the wound is desirable, and for this purpose, if necessary, the lower orifice of the tube is to be pinched sometimes while

[1] "Through Drainage" in the Treatment of Open Wounds. American Journal of the Medical Sciences, April, 1880, vol. lxxix., p. 305.

the injection is being made. Professor Markoe adds that every case thus treated, of a large number of severe injuries suitable for the treatment, chiefly compound fractures, went through its successive stages without inflammation at any time sufficient to defeat repair, and that in every case the result was equal to the best attained in the most favorable instances of the given traumatism.

ACCESSORY MEANS OF WOUND-CLEANLINESS.

Second only to the means used for cleansing the wound-surfaces themselves, are to be regarded those for cleansing the tissues adjacent to the wound, and for purifying all substances, such as the hands of the surgeon, instruments, retaining and protective dressings, and the air itself, which are brought in contact with the wound. These require consideration in this connection.

Adjacent Skin.—All that portion of the surrounding integument which is to be included with the wound under the protective dressings must be thoroughly disinfected. In the case of operative wounds, inflicted by the surgeon, this disinfection should be done before making the wound; in the case of accidental wounds, it should be done before applying the dressings. The skin should be shaven, and then thoroughly scrubbed with a flesh-brush and with soap and water, or even with ether, to remove fatty matters, and finally well washed with a penetrating antiseptic solution (carbolic acid, 1 to 20, or preferably corrosive sublimate, 1 to 1,000), the antiseptic solution being allowed to act for some time. Whenever the dressings are removed, the purification of the surrounding skin is to be repeated; and in the treatment of wounds in specially septic regions, as the axilla and perineo-scrotal regions, the dressings should be renewed with more frequency than in other regions, for the purpose of preventing auto-infection.

The Surgeon and his Assistants.—The hands of all persons employed about a wound should be thoroughly purified. What has already been said about the purification of the patient's skin applies equally to the skin of the hands of those caring for him. Especial care is to be directed to the folds of skin about the nails. The nails must be well pared, and thorough scrubbing with a nail-brush employed, first using soap and water, and afterwards an antiseptic lotion—carbolic acid 1 to 40, or corrosive sublimate 1 to 1,000. As the dust and dandruff which may be shaken from the

hair of the head or of the beard of a surgeon as he bends over a wound may be septic, it will not seem too great a refinement of cleanliness if their purification also be attended to in cases where absolute asepsis is of especial importance. The use of a snugly fitting cap to confine the hair commends itself as a cleanly procedure quite as meet for the surgeon who makes or dresses a wound, as for the cook who adopts such a device to prevent mingling the impurities shed from his hair from falling into the victuals that he prepares. Close clipping of the beard, or better, its entire removal, may not be a point too insignificant to be regarded. The condition of his mouth and nasal passages is to be regarded by a surgeon who would protect the wounds he cares for from contamination by his breath. The clothing worn should also be scrutinized. Clean white "dusters," or other easily cleansed "over-all" covering, upon which no stains could pass unnoticed, should be worn.

The towels and napkins used for wiping the hands should themselves be clean and still damp with an antiseptic liquid, out of which they have just been wrung. Care is to be exercised that the hands, after having been in contact with any non-purified substance, be not used about the wound until they have again been purified by dipping them in an antiseptic solution.

Instruments and Appliances.—Even though scrupulous cleanliness, as commonly understood, be observed with instruments and other appliances used about a wound, they may still bear septic dust, and introduce infection into a wound. Surgical cleanliness demands, however, that every instrument be absolutely free from living organisms or their germs when it is used. For this purpose instruments should be immersed in an antiseptic solution of sufficient strength (carbolic acid 1 to 20 the best; corrosive sublimate solutions corrode steel instruments, and hence are not available) for some time before being used. They are not to be merely dipped in; they must remain in the lotion for some time; the whole instrument must be immersed, and so arranged as to permit the fluid to come in contact with all its parts. An instrument, thus purified, if laid down on an unpurified surface should be regarded as contaminated, and should not be used again until it has been repurified by being dipped in the antiseptic lotion. The drains, the ligatures, and the sutures must each have been previously immersed in antiseptic liquids sufficiently long to have been made completely aseptic, and must be retained in an antiseptic lotion until the moment of use. Details of the treatment needed to make asep-

tic the different substances used for these purposes are considered in other connections.

Compresses and Protective Appliances.—The external dressings which are applied for the purpose of maintaining apposition in a wound, of exercising compression upon it, and of affording protection to it, must satisfy certain conditions of cleanliness, if they are not to become agents of harm rather than good to the wounds to which they may be applied. While they must be soft and mechanically unirritating, and must be capable of absorbing whatever secretions emerge from the wound, and thus contribute to the efficacy of drainage, they must also themselves be free from noxious organisms; and, finally, if they are to answer the most important requirement of protection, they must be able in turn to disinfect the secretions received by them and the air which filters through them. Many substances have been used which more or less perfectly satisfy these conditions. Cotton wool and loosely woven cotton cloth (book-muslin, tarlatan, cheese-cloth, gauze), lint, jute, turf-mould, charcoal, sand, and sawdust are the chief agents which are in use for wound-dressings at the present time. But to fit them to completely answer the requirements of wound-cleanliness by acting as efficient protectives against the access of noxious organisms, it is necessary that they should each be charged with some special antiseptic substance. This will be considered at length in Chapter X.

Purification of the Air.—Means of isolation and ventilation; the choice of a room upon an upper floor; the observation of cleanliness in all the surroundings of the wounded person; these are the only agencies to be relied upon to purify the air which must come in contact with wound-surfaces while they are exposed. The dressings which are applied to a wound should be of a character to purify the air which filters through them as long as they are applied. Should, however, in any case, it be deemed important to endeavor to secure the possible additional purification of the air which washing it by a cloud of spray might produce, a steam spray-producer would be needed to furnish the necessary volume of spray. The ordinary spray instrument of Mr. Lister (Fig. 45) answers as a model for such instruments. In this instrument a current of steam is made to rush through a horizontal tube over a minute orifice at the top of a more or less vertical one, the lower end of which is dipped in water, or a watery solution of the antiseptic, if one be used. In this way a vacuum is produced in the vertical tube, and the fluid at its lower end rises, and

is expelled from the upper orifice in the form of spray. The fluid used by Mr. Lister for his spray is a solution of carbolic acid, 1 to 20. After having been mixed with the steam, it is still further reduced in strength, the spray being estimated to contain the acid in the proportion of between 1 to 30 and 1 to 35.

FIG. 45.—The Ordinary Steam Spray-producer of Mr. Lister.

Steam spray-producers of various models, which differ from that of Mr. Lister only in minor details, are made by many instrument manufacturers in this country.

To obtain the full benefit of a spray in purifying the air of a room, the volume of the spray should be large enough to diffuse it over the whole area of the room. The use of several instruments placed in different parts of the room would be better than the use of but one, however large. The spray should be projected near the ceiling, that it might fall through the entire mass of air in the room, and should be continued for an hour before the exposure of the wound.

As the effect of the spray is to mechanically precipitate upon the surfaces upon which it falls the floating dust of the air, it should not be permitted to fall directly upon a wound-surface. While the wound is exposed its use should be suspended, except at a distance to wash currents of air as they enter the room.

CLEANSING SEPTIC WOUNDS.

If a wound has been exposed for some time and has already become ill-smelling, suppurating, and inflamed, energetic and thorough measures for the complete disinfection of the wound are necessary. Although such a wound cannot always be made aseptic, the effort to produce such a condition should be made. In such wounds it is to be remembered that it is not

only the discharges and the superficial surfaces in which the septic germs exist and must be destroyed, but that these organisms have infiltrated to a varying extent the subjacent tissues. As a preliminary to any cleansing

Fig. 46.—Volkmann's Sharp Spoon.

applications it is important that all wound-cavities and recesses be freely laid open, as far as possible. The mere conversion of a penetrating or sinuous wound-track into a free superficial wound, is sufficient of itself to rapidly modify the intensity of its septicity and to encourage more healthy granulation in its cavity. Free exposure of the wound-recesses having been done, all blood-clot and disorganized tissue should be removed, with any wound-secretions that may have been retained. Should an unhealthy granulating surface be exposed, as is the case in many chronically suppurating wounds, the soft granulation-material should be scraped away just as has long been the practice in dealing with carious bones, and as is most

Fig. 47.—Von Bruns' Spoon Curettes.

systematically and perfectly done by dentists in the treatment of carious teeth. For this purpose spoon-shaped curettes, as those of Volkmann, Fig. 46, or of von Bruns, Fig. 47, are efficient. They scrape away all the

soft inflammatory material, but are not sharp enough to materially attack the healthy soft parts beneath. The finger-nail of the surgeon in many cases will answer perfectly the needs of a curette. In addition, when tissues are evidently infiltrated with septic matter, they should be cut away or scarified deeply to admit of the more perfect penetration of antiseptic applications.

In all irregular wounds, and in those opening into cavities, in which it is not practicable to freely lay the entire track of the wound open, counter-openings should be made at suitable points to insure free through irrigation of all the recesses of the wound or cavity.

After this preliminary preparation the wound must be irrigated with a strong, germicidal lotion. Every recess of the wound must be reached by the disinfecting fluid. The lotion must be used in sufficient quantity to thoroughly soak the tissues. Success in rendering the wound aseptic will depend on the thoroughness with which this final disinfection is done. In an open wound, under otherwise favorable circumstances, this is usually not very difficult to accomplish; but when septic changes have been going on for some time in irregular cavities, or in cases of septic phlegmon extending into the intermuscular spaces, in suppuration of the articulations, or in severe compound fractures, it is always difficult (MacCormac).

Chloride of zinc is to be preferred as the germicide to disinfect septic wounds, because its caustic effect causes the disinfection produced by it to extend more deeply into the subjacent tissues, and because the protective film, which its combination with the albuminoids of the tissues produces, resists for so long a time the effects of any septic matters still remaining in other parts of the wound or introduced from without. The eight per cent. solution (forty grains to the ounce of water) should be used. It may be applied by irrigation, and, in addition, the wound-cavity should be filled with compresses soaked in the fluid.

Carbolic acid, by reason of its volatility and its diffusibility, may be preferred for injecting irregular cavities and narrow sinuses. The stronger solution, five per cent., is to be used until the wound has been rendered completely aseptic. In the after-cares more dilute solutions, whether of the zinc or of the acid, may be used. Throughout the future course of such a wound, greater care and watchfulness against the possible redevelopment of septicity will be required than would be deemed necessary in the management of a wound aseptic from the first.

CHAPTER IX.

APPOSITION OF THE WOUND-SURFACES.

Position—*Bandaging*—Rollers—Compresses—Adhesive Plaster—Icthyocolla Plaster—Gold-beater's Skin—Collodion—Application of Adhesive Bandage—Objections to Adhesive Bandages—*Suturing*—Needles—Needle-holders—*Thread*—Silk—Catgut—Silk-worm-gut—Horse-hair—Metal Wire—*Application of the Suture*—Stitches of Coaptation, of Approximation, of Relaxation—Knotting—Removing the Stitches—*Classification of Sutures*—Interrupted—Continuous—Pin—Quill—Bead—Button—Résumé.

The apposition of the separated surfaces of a wound is to be accomplished by Position, Bandaging, and Suturing.

POSITION.

The advantage to be derived from position becomes apparent when attention is directed to the effect upon the spontaneous gaping of the wound of varying attitudes of the wounded part. A wound over the front of the knee gapes widely when the knee is bent, though it may show but slight tendency to open when the knee is extended. The edges of a transverse wound upon the anterior surface of the neck fall together when the head is inclined forward, while a similar wound on the back of the neck is made to gape by the same movement. Wounds dividing muscles transversely gape most widely when positions are assumed in which such muscles are put upon the stretch. The general rule, therefore, which is to be observed as to the position of a wounded part, in attempting to secure and maintain apposition of the wound-surfaces, is that the part should be placed in that position in which the greatest relaxation of the parts can be secured. In this position they should be fixed and held until firm union has been accomplished.

BANDAGING.

Bandages to approximate separated parts may be either roller bandages encircling the entire member, or bandages dressed with adhesive material — adhesive plaster—short strips of which, passing across the wound and adhering to the skin on either side, suffice to keep the parts apposed.

Fig. 48.—Double-headed Roller.

A simple roller-bandage may be all that is required to perfectly approximate longitudinal wounds, and wounds in which there is little tendency to gape, or in which that tendency has been overcome by attention to position. By the use of the double-headed roller, as in Fig. 48, or the invaginated bandage, as in Fig. 49, the tissues may be made to slide toward each other from either side, and perfect apposition be secured in many cases. In all deep wounds the assistance of a bandage and of compresses is indispensable in maintaining apposition of the deeper parts of the wound. The compresses should be placed on either side of the wound, and upon it, in such position that the encircling bandage shall through it produce especial pressure of the deeper surfaces of the wound against each other. In the case of certain wounds, as of the face, neck, and trunk, in which the use of a roller bandage is impracticable, relaxation

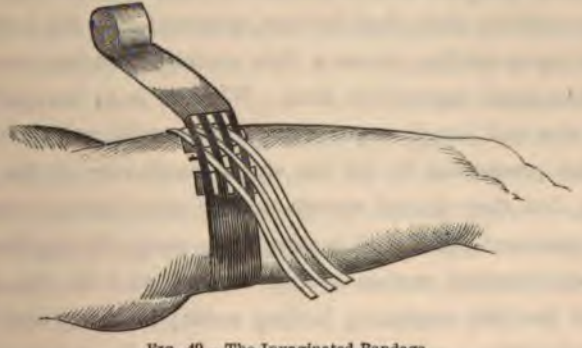


Fig. 49.—The Invaginated Bandage.

and compression of the wounded parts, so as to insure their continued apposition, is best accomplished by carrying broad strips of adhesive plaster across the wound, so as to grasp the tissues for some distance on either

side after these have been crowded up toward the wound by the hands of an assistant, so as to take off all tension in the wound itself. Underneath these strips and upon the wound compresses may be placed, of sufficient bulk to insure continued pressure of the wound-surfaces against each other. When a bandage is applied at any part of a limb so as to encircle it, its application must be preceded by careful bandaging of the distal portion of the limb, from the fingers or toes to the seat of injury, to prevent strangulation.

Rollers.—The material out of which the bandages shall be made should be soft, strong, and somewhat elastic, so as to adapt itself snugly to the parts to which it is applied. Cotton cloth—muslin sheeting—that has been repeatedly washed and freed from the stiffness of the new material, is usually available, and answers well the purposes of a bandage. Material that has been worn until it is tender should be rejected. The loosely woven cheese-cloth, or gauze, when attainable, is to be preferred, in most cases, to ordinary muslin. It is lighter, cooler, more elastic, and permits the passage of discharges more freely through it. Cloth of any kind should always be torn in the direction of its length in making it into bandage strips.

Compresses.—Purified cotton-wool is the best material for use as compresses. It is unirritating, light, elastic, and absorbent. Folds of gauze, masses of charpie, of oakum, or other similar substances may be likewise used with advantage.

Adhesive Plaster.—The ordinary adhesive plaster consists of muslin which has been smeared with a mixture of litharge, olive oil, resin, and soap. This mixture, while fluid by heat, is spread over the surface of the muslin, and upon cooling forms a thin coating, that becomes soft and adhesive when again exposed to heat. When it is to be applied, strips of suitable size and length are cut from the muslin roll thus prepared, observing the precaution to cut the strips lengthwise of the cloth, not transversely, lest they should stretch unduly after having been applied. The most convenient method of heating these strips for application is by pressing their unspread surface against a vessel, as a tin cup, a bottle, a tea-kettle, or the like, containing boiling water; they may also be heated, but less conveniently, by exposing them to an open fire, holding them over the chimney of a lighted lamp, before a gas-light, etc. A form of adhesive plaster which does not require to be heated before it is applied, was introduced to notice in 1877, by Dr. Henry A. Martin, of Boston, Mass., which

has received much favor, and, under the name of "Rubber Plaster," has been since imitated by many makers. The adhesive coating of this plaster is composed of Para rubber, Burgundy pitch, and balsam of Tolu. It is flexible, water-proof, comparatively unirritating, and does not deteriorate with keeping, and it is to be applied at once without any preparation.

Ichthyocolla and skin plasters, and collodion may serve as substitutes for the ordinary adhesive plaster in the approximation of small and superficial wounds.

Ichthyocolla Plaster is made by applying to silk a solution of isinglass in alcohol. When it is to be applied, it has simply to be moistened by passing a damp sponge over its glazed surface. Its adhesive properties are weak, and it cannot be used where there is moisture, so that its use is restricted rather to the amateur dressings of the laity, to whom its greater elegance of appearance and the ease of its application commend it. What is called *court plaster* is a variety of isinglass plaster.

Gold-beater's Skin.—A delicate membranous film, made from the intestine of the sheep or the peritoneum of the bullock, when applied to a moistened surface adheres with sufficient firmness to withstand considerable traction. It is applicable particularly to slight wounds of the eyelids, or as a protective layer over an excoriated surface.

Collodion.—A solution of freshly prepared gun-cotton in ether, assisted by a little alcohol, when applied to a dry surface, by the rapid evaporation of the ether, leaves a transparent film that adheres strongly and contracts considerably. It may thus be used for fastening strips of silk or muslin to the edges of a wound, in place of other adhesive material, or may be applied directly over the wound as the only dressing, or as supplementary to other agents in sealing up the wound. It is most useful as a final application to wounds that have healed, upon the withdrawal of other dressings, applied over the cicatrix which it protects, giving it a needed support in resisting the inevitable tendency to reopening of the wound, which may be more than the fresh and tender new uniting material can withstand.

The Application of the adhesive Bandage.—The skin to which a strip of adhesive plaster is to be applied should be shaven, well washed with soap and water, and carefully dried, to present a surface to which the plaster can adhere, and to save the patient from the pain that would be caused by their removal if the hair was adherent to the plaster. One end of the strip is then to be pressed upon the skin upon one side of the wound, and while the edges of the wound are held together by the surgeon, the strip is car-

ried across and fastened upon the other side. Care is to be exercised that inversion of the edges of the wound be not occasioned, and equal care that sufficiently firm approximation is secured to prevent their after separation. The first strip should be placed across the middle of the wound, and an interval of from one-quarter to one-half an inch left between each succeeding one, to admit of the escape in the intervals of wound secretions. As soon as strips thus applied lose their hold, become sources of irritation or obstruct drainage, they should be removed. But unless some such indication exists meddling with them is objectionable, as it tends to do injury to the healing of the wound. The cleansing of the wound is to be limited to gently wiping from the surface of the wound and of the dressings whatever secretions may have gathered there. When the removal of the plasters is necessary, gentleness of manipulation must be observed; the two ends of each strip should be lifted first, and the central part last detached from the line of the wound itself, lest by dragging the strips from one side to the other the wound be reopened.

Objections to adhesive Bandages.—The use of adhesive bandages for the purpose of producing direct apposition of wound-surfaces is objectionable from its interference with wound cleanliness. The muslin strips may themselves be carriers of infection, unless they are disinfected with equal care with everything else that is allowed to come in contact with the wound. They may favor infection again by sealing up that portion of skin upon which they are laid from the action of the antiseptic dressings that may be applied over them, and thus fostering the creation underneath them of foci of sepsis from the development of organisms hidden in the depressions and follicles of the skin that will have escaped the primary disinfection of the part, however thoroughly done. Still farther, extending as they must some distance in every direction from the wound, as soon as they become wetted with the wound-discharges, they become favorable media for the propagation from the periphery of the dressings inward to the wound of micro-organisms from without. In addition to these objections, which are of vital importance in efforts at preserving asepticity in wounds, they are also chargeable with being unreliable in the support they may give from their tendency to become loosened, with irritating in many cases the skin to which they are applied, and, finally, with covering up the wound from the inspection of the surgeon. For these reasons, the use of adhesive bandages as direct applications to wound flaps to secure their apposition, should be abandoned in the great majority of cases. For

purposes of supplementary support, for use outside of the dressings applied immediately to the wound, to prevent tension, to produce compression, and to insure fixation of the dressings, they are invaluable.

SUTURING.

The suture is the most certain, exact, and important of all methods of obtaining apposition of divided surfaces. Position and the various methods of bandaging are chiefly to be employed as supplementary to the suture.

The application of the suture is simply the use by the surgeon of the tailor's art to sew together the separated tissues, and by a thread to retain them in apposition until their permanent union by a bond of newly-formed living tissue can be effected.

Sutures may be applied superficially and close to the wound-margins, simply for the purpose of keeping the cutaneous edges of the wound in apposition, such stitches being technically called "stitches of coaptation;" or more deeply and at a greater distance from the wound-margins to approximate and maintain in apposition the deeper surfaces, "stitches of approximation;" or at a greater distance yet from the wound, for the purpose of relaxing the adjacent tissues so that the wound-surfaces may be brought together, and tension upon the stitches applied to keep them in apposition may be prevented, these latter constitute "stitches of relaxation."

For the practise of the suture there are required needles, thread, and in some cases needle forceps for the more convenient insertion of the needles in the tissues. The peculiarities of the tissues to be sewed makes certain qualities important to be possessed by each of these agents; these, therefore, require consideration here.

Needles.—The density and elasticity of the tissues to be penetrated by the surgical needle makes it necessary that it should differ from the ordinary sewing needle by having its point flattened, and the edges immediately following the point sharp, giving the forepart of the needle the shape of a lance (Fig. 50, A). The point should be fine, and the cutting edges should extend but a short distance back from the point, and should exceed in its transverse diameter that of the shank or thread extremity of the needle. The eye should be as large as possible, to avoid delays in threading, and its edges should be well rounded, so as not to cut the thread. Their thickness and length vary greatly, according to the size of the thread to be used and the thickness of the tissues to be penetrated.

The shape of the needle must vary with the locality in which the suture is to be applied. Upon a plain or convex surface, when the stitch is to be introduced but superficially, a straight or but slightly curved needle (Fig. 50, A and B) is most convenient; where the tissues are to be deeply pene-

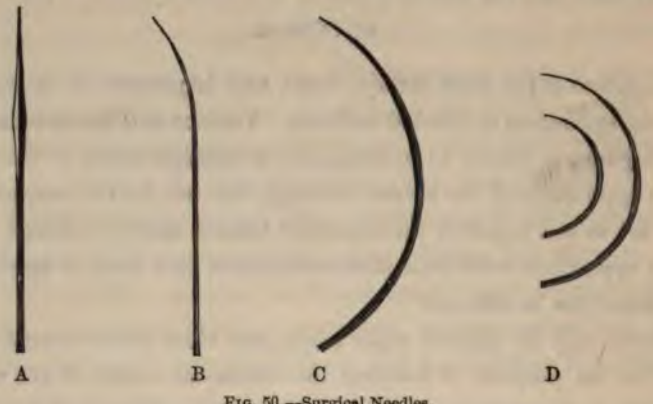


Fig. 50.—Surgical Needles.

trated, or the wound involves a concave surface, as at the inner canthus of the eye, or the perineum, strongly curved needles (Fig. 50, C and D) become necessary.

The steel of which they are made should not be too hard, lest they break easily. The chief points to be regarded in the choice of needles are that they have good points, keen sides, and sufficient temper to prevent their yielding to the force necessary to their introduction.

Needle-holders.—When a suture is to be made with a small and much curved needle, or in a cavity, the needle cannot be managed by the fingers, but must be seized and held firmly in a needle-holder. Any forceps with short stout jaws, and long handles that can be grasped and held firmly in the hand, will answer for a needle-holder. The forcipressure for-

Fig. 51.—The Needle-holder of Dieffenbach.

ceps of Wells (Fig. 11) are a good model. The catch, by means of which the branches are fastened when they are closed, adds greatly to their convenience in use.

Fig. 51 represents the needle-holder of Dieffenbach. Fig. 52 that o Sands.

Of the many models which have been constructed, the writer prefers that known as the "Russian Needle-holder" (Fig. 53), devised by Dr. Anatol de Gaine, of St. Petersburg. The firmness with which it holds the needle, the ease with which by a simple mechanism it can be locked and

FIG. 52.—The Needle-holder of Sands.

unlocked, and the shape of its handles, whereby both delicacy and power of manipulation is secured, constitute its merits.

The inner surface of the jaws should be cut into stellate grooves, or should be lined by pewter, into which the needle when grasped may sink and be held securely. Many varieties of needle-holders have been devised to facilitate the introduction of sutures in deep cavities and special localities. The requirements for a needle-holder are that it shall immovably grasp the needle, that it shall be of a shape to be itself securely grasped by the hand of the surgeon, and that its mechanism shall secure the rapid picking up and quick letting go of the needle.

FIG. 53.—The Russian Needle-holder.

THE THREAD.—The suture requires that the thread-material shall be fine and smooth, sufficiently strong to stand a certain amount of strain, soft and pliable, so that it adapts itself well to the eye of the needle, easily pulled through the tissues after the needle, readily tied into a knot, and susceptible of being removed with equal readiness. The agents that are worthy of special mention as being in most general use, and as answering the purposes of the suture most satisfactorily, are threads of silk, of catgut, of silk-worm-gut, of horse-hair, and of metal.

Silk.—As fine a thread should be chosen as will bear the strain of the suture, for the observations of Simon [1] and Billroth [2] have shown that the

[1] *Experimente über verschiedene substanzen zur Wundnaht.* Rostock, 1862.

[2] Surgical Pathology. Hackley. New York, 1871.

finer the thread the less irritation its pressure in the tissues would occasion, so that very fine ones might cause no irritation whatever, but become healed in like metal ones. The finest size of what is called, in the instrument shops, braided ligature silk—size No. 1—though it is as fine as a hair, is very strong—strong enough to bear any tension that ought to be put on a suture, and does not kink or curl. Silk should be made aseptic before using by immersing it in a solution of carbolic acid or of corrosive sublimate, as described on page 112.

Catgut.—Properly prepared and seasoned catgut answers every purpose of a suture material. Only that which has been prepared after the methods described for catgut ligatures, page 110, should be used for sutures. In general, after a few days the absorption of the loop embedded in the tissues sets free the knot, which is then washed away or picked off without other manipulation for its removal. The gut seasoned with chromic acid—chromic gut—resists the solvent action of the tissues for from ten to twenty days. Being unirritating, it may be left undisturbed as long as the wound-cicatrix may need support. The catgut, however, is not quite so manageable as the aseptic silk; it is a little more troublesome to tie the knots securely; it is more difficult to secure with it an exact and fine coaptation of the edges of the wound; the material is more expensive and the preparation is more troublesome; the spontaneous melting away of the loop in the tissues may take place prematurely; for these reasons it has not supplanted the silk thread for general use.

Silk-worm-gut.—This is made from the organ of the silk-worm which furnishes the material out of which the cocoon is woven. The threads obtained are polished, transparent, and very smooth, and are especially distinguished by their great strength in comparison with their thickness; they are stronger than metal threads, and will remain unchanged in the tissues for a month. They produce no irritation, but they have the disadvantage of being somewhat stiff, so that some difficulty attends tying them in a sufficiently strong knot. To render them more pliable they should be soaked some time in water (carbolized or sublimated) before being used. Sutures of this material are most in favor among those surgeons who use catgut but little. They have been especially praised for cases of ruptured perineum and vaginal fistula, and fissured palate. The improvements made in silk by rendering it aseptic, and in catgut by chromicizing it, have lessened the frequency with which the silk-worm-gut is likely to be resorted to.

Horse-hair.—The pliancy, delicacy, smoothness, and non-irritating qualities of horse-hair make it a desirable substance for sutures, and it deserves more attention than it has usually received. It is strong enough to keep the lips of an ordinary wound in apposition; a double strand may be used if necessary. It remains unchanged indefinitely in the tissues, and may be permitted to remain as long as the support of a suture is required. It can be applied with the usual surgical needle, but needs more care in making a satisfactory knot than does silk. If there is any tension upon it, the first knot needs to be held by a forceps to prevent slipping while the second is being tied. It is easily removed by snipping with a pair of scissors, and withdrawal by an ordinary pair of forceps, with absolutely no discomfort to the patient, being in this respect in marked contrast with metallic sutures. Hairs from the horse's tail, selected for their size and strength, are to be preferred. They should be prepared for use by washing in an alkaline solution, and should be immersed in an antiseptic solution before being introduced. Its abundance and the readiness with which it can be obtained, costing nothing but the slight trouble of cleansing it, together with the advantages possessed by it, as enumerated, as a suture, would make the use of horse-hair general for all ordinary wounds, were it not that the silk thread is more convenient to tie and to carry by reason of its greater pliability. In default, however, of proper silk, it is a most valuable substitute.

Metal.—Fine metallic wires, of lead, of copper covered with gutta-percha, of iron, or of silver, and even of other metals, may be used for the purposes of a suture; by their smoothness, pliability, and freedom from irritating properties, they combine in an eminent degree the qualifications demanded for such use. They may be introduced with an ordinary surgical needle like thread, although a needle whose head, from the eye to the extremity, is grooved for the reception of the wire, facilitates their introduction; they are easily fastened by twisting the ends together. They are particularly of value for wounds in which great accuracy of coaptation is desired, on account of the facility with which they can be readjusted by simply untwisting the ends, and with which, also, the tension they shall exert may be regulated by the degree to which the twisting is carried. They also tend to support and immobilize the tissues through which they pass, and contribute in this way in no mean degree to promoting early union. The ease with which they are fastened adapts them especially for use in deep cavities. There is no necessity for their early

removal, and they may be left undisturbed till the parts are firmly united. Silver wire is the kind of metal thread most frequently employed. Wire made of it as fine as a hair possesses sufficient strength, and is very light, soft, and pliable. The first use of it for sutures was made by J. Marion Sims,[1] in the treatment of vesico-vaginal fistulæ, in 1849, and his enthusiastic advocacy of its merits in succeeding publications attracted general attention to its use in general surgery. In his "Anniversary Discourse before the New York Academy of Medicine," in 1857, he declares it to be his "honest and heartfelt conviction, that the use of silver as a suture is the great surgical achievement of the nineteenth century!" The experiments of Simon, already alluded to, however, demonstrated that there was no difference in the amount of irritation produced in the tracks of a very fine well-twisted silk thread and a fine metal thread during the first eight days of their residence in the tissues. Since both the introduction and the removal of the wire demands more care than silk on account of its inferior softness and pliability, they are not so well adapted as the fine silk to unite wounds the edges of which are thin. Even in uniting the edges of the wound produced in the operation for the relief of vesico-vaginal fistula, in which Sims first used silver wire with so much advantage, surgeons of the present day obtain equally good results with silk and catgut. Silk has still maintained its place, therefore, as the agent most generally employed; but for deep sutures, especially those which are applied for the purpose of relaxing the wound-borders, and for suturing bones, and whenever strong tension is to be borne by the suture, and when the suture must remain *in situ* for a long time, an unqualified preference must be given to the silver wire.

Application of the Suture.—It is important as the first preliminary, when a suture is to be applied, that the surgeon shall assure himself of the cleanliness of the suture materials, in the aseptic sense of the term clean. The needles should be immersed in a five per cent. solution of carbolic acid, and whatever form of thread is deemed best should have been rendered aseptic by previous preparation, and should likewise be anew immersed in the antiseptic solution at the time that it is to be used.

Before the introduction of a suture the wound-borders should be carefully coapted throughout their whole length, in order that they may come evenly together—not having a wrinkle in one place, and a projecting end

[1] The Treatment of Vesico-vaginal Fistula. American Journal of the Medical Sciences, January, 1852.

in another. To secure this the proper points for entrance and exit of the needle through the skin should be noted, and when the wound is a long one, it will be best to introduce the first stitch in the centre. If the new stitches on either side are likewise placed half-way between the first one and the angles of the wound, the long wound is thereby changed into four small ones, the perfect adjustment of whose edges is much facilitated.

If several sutures are to be applied, it is better to have the necessary number of needles already threaded and conveniently placed within reach. Not only is the delay necessary to newly thread a needle in the course of the operation inconvenient, but it is more likely to be attended with some infraction of the laws of cleanliness.

Fig. 54.—The Seizure of the Needle (*Fischer*).

The needle should be seized by the right hand so that the middle finger shall be on the one side and the thumb on the other, and the index finger by the side of the middle finger where the needle is curved, with both ends of the thread hanging thrown over the backs of the fingers. (See Fig. 54.) The border of the wound should then be steadied by seizing it with a forceps or tenaculum, while the needle is made to transfix the tissues. When the wound flap is sufficiently extensive and free, it may be fixed by grasping it with the thumb and finger of the left hand. Upon a convex surface, or even a flat surface, when the stitch is to be very superficial, it is possible to depress the eye end of the needle, and to elevate the wound-borders sufficiently to enable the transfixion to be made with a straight needle, but on a concave portion of the surface of the body, as between the nose and cheek, the palm of the hand, perineum, etc., a curved needle is required. Since also a curved needle is equally of use on any surface, it is the instrument ordinarily and generally used for any suture. The needle should pass through the tissues in a line about equal to its own curvature; when but a small amount of tissue is to be included in the suture, the needle entering and escaping near the line of intended union, a short and strongly curved needle is needed; if the suture is to be

introduced at a greater distance from the wound-edge, a longer and less strongly curved needle is required.

The distance from the edge at which the needle shall be introduced, and the depth to which it shall be carried will depend upon the particular function the suture is intended to discharge. For a stitch of coaptation, the needle will be introduced from two to three-sixteenths of an inch from the edge, and will be thrust through the skin into the subcutaneous connective tissue only. Stitches of approximation will be introduced at a greater distance, and will pass more deeply among the tissues. The two may be used alternately. Fig. 55 illustrates the arrangement and rela-

FIG. 55.—Stitches of Coaptation and Approximation Introduced (*Fischer*).

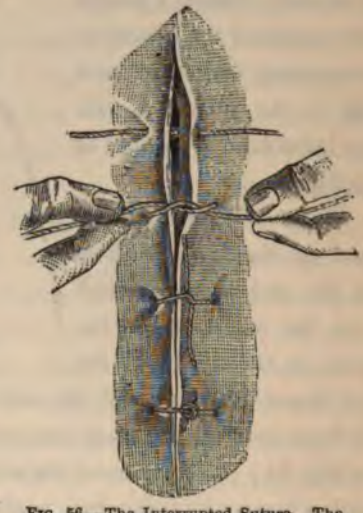


FIG. 56.—The Interrupted Suture. The Knotting of the Suture (*Fischer*).

tions of these two kinds of stitches. When deep sutures are inserted a tendency to incurvation of the wound-edges is produced, to overcome which requires care to alternately elevate either edge with a tenaculum or forceps as the suture is tied.

When the point of the needle has emerged from the opposite flap of the wound, it is to be seized with the fingers, or forceps, and drawn through, carrying a sufficient length of thread after it to admit of being conveniently tied into a knot. The ends are then brought together so as to bring the wound-surfaces into apposition and tied into a secure knot. The various steps of this knotting of the suture are depicted in Fig. 56. The suture must not be drawn so tightly as to strangulate the tissues embraced in its loop. A suture drawn too tightly will speedily provoke in-

flammation and suppuration. Nor must the suture be subjected to much elastic tension of the tissues, otherwise the tissues will cut themselves upon the unyielding thread until the suture becomes loose. When the tissues are lax the ordinary reef-knot, Fig. 57, should be made as the most secure form of a knot.

If there exists much tendency to gaping in forming the first knot, the thread may be passed twice through the same noose, Fig. 58, so that the adhesion of the threads is increased sufficiently to resist the tendency to retraction of the edges until the second simple knot can be tied. This is what is termed the "surgical knot." If the two lips can be held in apposition by an assistant while the knot is tied, the surgical knot will be superfluous.

FIG. 57.—Reef-knot.

FIG. 58.—Surgical Knot.

The knot must not be tied so as to come in the wound-line, but must be tied on one side so as to press upon the sound integument, for when the knots are permitted to press directly upon the line of the wound they are liable to produce irritation.

The distance between the points of suture must vary according to circumstances, depending upon the tendency to gape of the tissues, and the importance for securing union by first intention of the most accurate apposition possible. In no case should there be allowed any gaping in the intervals between the stitches. The intervals may vary from one-eighth to one-half or three-quarters of an inch. No fixed rule can be laid down, either, as to the succession in which the stitches shall be applied, beyond the general principle that the stitches of relaxation are to be first applied, then the stitches of approximation, and finally the stitches of coaptation. It is easily apparent when the wound-edges are brought together at what point the first stitch should be placed. In angular wounds the point of the angle should first be secured, and subsequently the stitches should be placed elsewhere, so that the borders throughout shall come smoothly together.

The stitches may be removed, as a rule, in about three days; but unless their longer residence in the tissues is attended with evident disadvantage, as shown by a tendency to produce irritation and ulceration, it is better to leave them undisturbed for forty-eight hours longer. When there has been much tension necessary to bring the edges of the wound together, too early removal of the stitches is especially to be avoided. A week or ten days is time enough. By the use of aseptic sutures the necessity for speedy removal of the thread is overcome, and the needs of the new uniting tissue for support can be more exclusively considered.

To remove the stitches, the knot should be seized with a dressing forceps, elevated slightly from the integument, so that the point of a scissors can be insinuated beneath it to cut the thread beyond it. The thread is then drawn carefully out, while the tissues are steadied by the scissors pressing upon them, and traction is made upon the thread in a direction toward the line of cicatrix lest the wound be torn open anew by the proceeding. The stitches first to be removed should be those of the least importance. In general, they will be removed in the reverse order of that with which they were introduced. After their removal, the parts should be supported for a time by strips of adhesive plaster, when the wound is in a locality where they can be applied, and the line of the cicatrix and the immediately adjacent skin should be covered with a layer of collodion.

Classification of Sutures.—According to the different methods used for the successive application of the stitches, or the different devices used for exerting pressure upon the tissues, sutures are divided into *interrupted, continuous, pin, quill, bead, and button* sutures.

Interrupted Suture.—The interrupted suture is formed of a series of separate stitches (Fig. 56). It is more generally used than any other form of suture; indeed, the pin, quill, button, and bead sutures are but forms of this suture. Stitches of relaxation and of approximation, in all cases, require to be of this form. It is the typical suture, and all that has preceded with reference to the technique of the suture is particularly applicable to the interrupted suture.

Continuous Suture.—This suture, on account of its similarity to that used by the glover, is frequently spoken of as the "glover's suture." The stitches of which it is composed are not separate, but are made with the same needle and thread, in continuous succession, by passing the needle diagonally from one side of the wound to the other over the surface, and through the tissues, until the whole extent of the wound has been tra-

versed (Fig. 59). Though this form of suture is especially adapted for sutures of coaptation, it had until recently been almost entirely discarded, except in the sewing up of wounds of the intestines. In nearly all cases, however, it is superior to the interrupted suture for coaptation purposes by reason of its greater simplicity, the greater rapidity with which the necessary coaptation can be secured, the more even and accurate apposition of the edges which it accomplishes, and the increased support to the whole line of the union that it gives. The resulting cicatrix will be more finely linear than can be obtained in any other way. In applying the continuous suture, a comparatively short, fine, aseptic silk or catgut thread should be used, which, with a straight or curved needle, according as the peculiarities of the locality may require, is introduced at one

FIG. 59.—The Continuous Suture.

angle of the wound, where it is tied as for the interrupted suture, and thence is carried with oblique stitches along the coapted wound-margins to the other end of the line of separation. Here the thread is fastened by leaving the superficial loop connecting the last two stitches so loose that by cutting it a free end is left which is tied to one end of the last stitch after this has been tied as an ordinary interrupted suture. For its removal, each superficial loop should be cut with the point of a scissors, converting it into as many points of interrupted suture, each one of which should then be carefully withdrawn as before described.

PIN SUTURE.—This form of suture, Fig. 60, known also as the twisted, and hare-lip suture, consists in transfixing the apposed margins of a wound with metallic pins, and then, while the wound surfaces are kept approximated by pressure from the fingers of an assistant, the two projecting ends of the pin are encircled with a thread, which is then carried several times around the pin, over the line of the wound elliptically, and in the shape of the figure 8, and lastly is secured by a knot.

As a pin to be used for the purposes of this suture, the ordinary glass-

headed ladies' toilet pin, Fig. 61, is not surpassed by any other device. It is very sharp-pointed, and readily penetrates the tissues; it is unirritating; it is quickly procurable, and is cheap. The German insect-pin, Fig. 60, which is made of brass with a ball head, and a flattened, lance-shaped point, likewise makes an excellent agent. Transfixion is effected in the same manner as in the common interrupted suture, the thumb and finger being generally quite sufficient for the purpose. The pins should be thrust as deeply into the tissues as is compatible with bringing them out again at a corresponding point upon the surface of the opposite flap. All the pins that are to be inserted should be put in place before the thread is

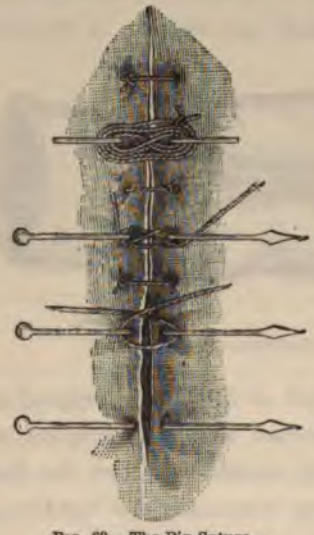


FIG. 60.—The Pin Suture.

FIG. 61.—Pin for Twisted Suture.

applied, otherwise the insertion of the second pin will pull unduly upon the first suture. The distance from the wound edges of the points of entrance and exit of the pins will be from one quarter to half an inch. The distance between the pins will depend upon the degree to which the wound borders tend to gape, and the amount of motion to which it will be exposed. Each pin should be separately wound about with the thread, which should then be cut and tied. In place of thread, narrow rings of rubber may be used to slip over the ends of the pins, and to compress the wound-borders. The points of the pins should then be cut off with a pair of pliers to prevent their sticking into the skin. If there is a tendency evident for the ends of the pins to press unduly into the skin, this may be protected by a strip of adhesive plaster inserted beneath the extremities

of the pins. The practice of taking a much longer thread and carrying it from one pin to another, making a cross likewise over the wound between the pins with the thread, as it passes from pin to pin, has the advantage of aiding their coaptation by the gentle pressure which it makes upon them, but this can be better accomplished by superficial sutures placed between the pins, as in Fig. 60, which may remain to support the tissues still longer after the pins have been withdrawn. The earlier removal of the pins without disadvantage is thus made possible ; this should be done in from two to three days, even earlier if the pins show a tendency to cut their way out. When they are to be removed the wound edges should be gently pressed together by the left thumb and forefinger, applied upon the ends of the twisted loops, the head of the pin should be grasped by an ordinary dressing-forceps, by gentle rotation their adhesion in the line of their penetration loosened, and then withdrawn. The thread loops, which are glued to the skin by dried blood, may be left in place for a day or two longer, as a bond of union, until they become spontaneously detached. All the pins may be removed at the same time, or at different times. In the latter case, those will first be removed that are least useful.

The pin suture is especially applicable in cases where there has been considerable loss of integument, and where considerable strain upon the tissues is necessary to bring them together. When the parts are very movable, as in the lips and cheeks, and also when the wound involves skin that is so thin and lax that the wound edges manifest a strong tendency to roll in. A much more frequent use of the pin suture might be made with advantage than is now usual. Though primarily it is important as a means of approximation when the divided surfaces are first brought into apposition, its secondary effect, to keep immovable and to support the united wound is no less important, and may make its use desirable when the first indication does not call for it. The results, in general, of attempts to obtain union by first intention in wounds of any extent will be much more uniformly successful by the use of the pin suture, as a matter of routine practice, than by relying simply on the ordinary suture and bandaging.

The Quill Suture.—This suture consists in the application, on either side of the wound, at a little distance from its edges, and parallel with them, of little rods of some smooth and unirritating substance, as a quill, bougie, whalebone, or soft wood, around which threads passed deeply across the wound were looped, so that when they were drawn upon and tied, the pressure of the rods would bring and hold together the deep

parts of the wound, and would relax the superficial parts, which were also secured by superficial stitches of the interrupted or continuous suture. The arrangement is shown in Fig. 62 and Fig. 63.

In making this suture, several needles should be threaded by passing both ends of the thread through the eye of the needle, so as to form a loop on the middle of the thread. The double thread is then to be passed, as deeply as may be necessary, through the wound-borders as for an ordinary interrupted suture. A sufficient number of threads having been introduced, instead of crossing them and tying, a rod is slipped through the loops on the one side of the wound, which are then tightened from the other side by drawing on the free ends. A similar rod is then placed between the free ends of the threads, and upon this they are firmly tied,

FIG. 62.—Quill Suture. In course of application.

FIG. 63.—Quill Suture. Application completed.

beginning with the central threads, which are drawn down upon the rod until by its pressure the wound surfaces are brought into close apposition. A secure knot is then tied, and the application of the apparatus is complete. This form of suture was used by the older surgeons for closing deep muscular wounds, as those of the thigh and abdomen; and by later surgeons more particularly for the repair of lacerations of the perineum. It is efficient both as a suture of approximation and relaxation, but for these purposes has been mostly superseded by the bead and the button suture in some form. In wounds in situations where the additional support of compresses and bandages are impracticable, it will, however, always remain as a device of great value for securing primary accurate deep apposition and consecutive immobilization and support during the healing of the wound. For its removal, after three to five days, the loops are cut with scissors on the one side, and the threads drawn out on the other.

THE BEAD SUTURE.—This is an interrupted suture in which two sutures are joined in one so that a bead at either lateral extremity of the suture has a wire or thread passing through the centre of the bead. The twist of the two ends of the wire enables the operator to tighten or loosen the tension after the suture line is closed. This is a very desirable quality of a stitch in a situation like that of the interior of the mouth, the stitch having no covering, and the suture line having no possible support except that of the stitches themselves. This suture is equally applicable to wounds in the vagina, where any support to the stitches is impracticable. It is thus described by Dr. David Prince, of Jacksonville, Ill.[1]

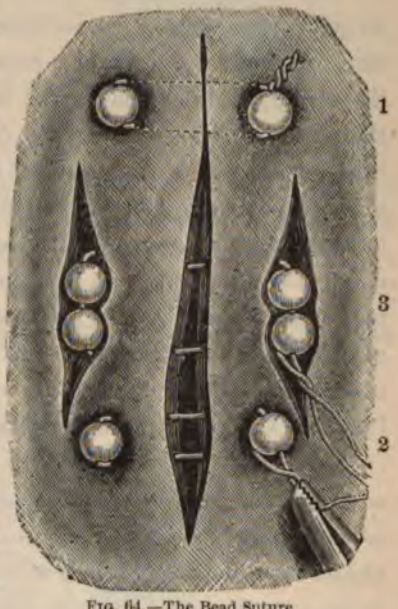


FIG. 64.—The Bead Suture.

The accompanying cut (Fig. 64) represents the suture in three stages: (1) The completed suture, the beads lying upon the natural surface of the skin or mucous membrane. The tightening or loosening of the twist of the ends of the wire increases or diminishes the tension. The dotted line indicates the course of the wires or threads through the tissues. At the bottom of the figure is seen (2) the same stitch incomplete. The open condition of the wound shows the wire passing through the cut surfaces. The suture can be so introduced into membranous, or in thin walled parts, that the wire will lie upon the surface opposite to that upon which the beads rest, if it is preferred. The position of the forceps, by which the ends of the wire are twisted, is seen in the cut (3). The double-beaded suture, in which (in the cut) the beads are seen to lie in a slit made parallel to the suture line, in order to enable the opposite surfaces to come into contact with each other. The beads sink into these incisions, and, as the wires pass through the tissues between the surfaces of a thin wall, there is no folding of the parts to prevent the cut surfaces of the suture line from being held in close and accurate contact.

The object in using two beads on a side is to increase the work done

[1] The Bead Suture. Annals of Anatomy and Surgery, March, 1883, p. 142.

by two wires, or a single wire bent upon itself, and to increase the scope of applied pressure. In place of two spherical beads, a single elliptical one may be employed. The polished glass bead is friendly to the surfaces, and, on account of its smoothness, it is superior to a sphere of lead. No attention is required to adjust spherical beads, and, as they lie loosely upon the silver wire, they are ready when the wire is cut, at the final removal of the stitches, to slip off without difficulty. The manner of introduction is very simple and easy. A pilot thread is first carried through in the situation in which the wire is to be subsequently introduced. A similar pilot thread is then carried through on the opposite side. Each pilot thread is double, and the loop ends are so related to each other that one thread may be included in the loop of the other, by which it is drawn through. A silver wire is then drawn in by the remaining thread. A bead (or two as the case may be) is slipped upon the wire, after which it is hooked upon the loop of the next thread and drawn in. The two ends of the silver wire are then on the same side. A bead (or two as the case may be) is then slipped on to one end of the wire, after which the application of the forceps is made preparatory to the final twist. In the removal of the suture, the wire may be cut at either end and on either side of the bead. The bead straightens the wire in slipping off, so that traction upon the other bead pulls the wire out, appearing then in the shape of a staple.

There are many situations in which the employment of the beaded suture will be found convenient and efficient. The principle of this stitch is not new, only the form and material of it. When this stitch is employed upon the soft palate it answers the purpose of a suture and a splint at the same time, and holds in continuous apposition parts that are in motion with every act of swallowing and speaking. The same advantage exists in operations for the closure of rents in the vagina, where movements occur in connection with the evacuation of the rectum and of the bladder.

The Button Suture.—For the purpose of securing relaxation of the more distant tissues, so that the wound surfaces may be approximated and coapted, the most efficient device is some form of metal plate, or button, placed on either side of the wound at appropriate distances, and joined by silver wire which is passed deeply through the tissues from plate to plate across and at the bottom of the wound. Traction upon the wires suffices to draw together the tissues pressed upon by the plates and to relax the intervening tissues. Whenever a considerable gap exists, such

sutures are of great value in facilitating healing, and should generally be employed. Various forms of plates have been used. None are more simple and efficient than the form devised by Mr. Lister, Fig. 65, which con-

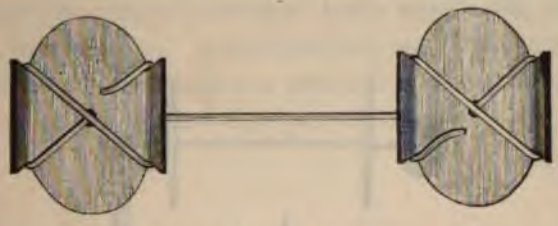


FIG. 65.—Lead Button for Stitch of Relaxation (*Cheyne*).

sists of a flat plate of lead, about one-twentieth of an inch in thickness, cut of an oval form, with lateral wings, which are turned up, and afford projecting edges about which the end of the wire is wound in a figure of 8 form, while the wire for the suture passes out through a hole that has been perforated through the centre of the plate. Fig. 66, from MacCormac's "Antiseptic Surgery," illustrates the method of the application of this

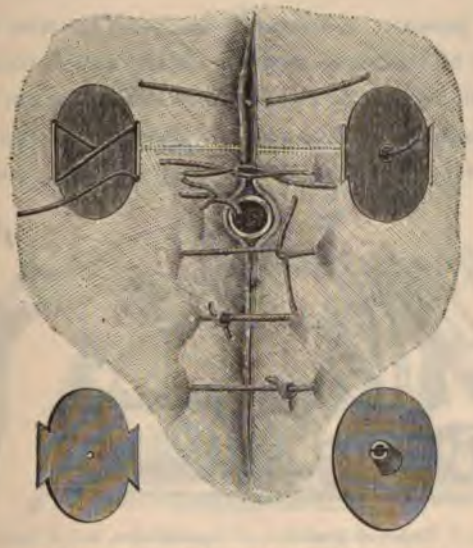


FIG. 66.—The Button Suture Applied (*MacCormac*).

lead plate or button. On the one side the wire is seen to be secured by winding it about the projecting wings as described; on the other it is secured by a split shot which has been clamped upon it. Another simple

and ingenious method, suggested by Thiersch, of Leipsic, is also figured by MacCormac, from which the accompanying cut (Fig. 67) and description are borrowed.

Outside a leaden plate is placed a small perforated glass bead, which

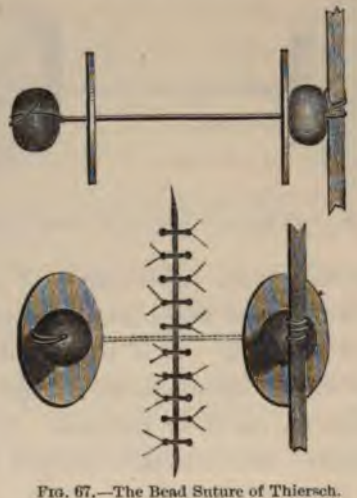


FIG. 67.—The Bead Suture of Thiersch.

distributes the pressure, and outside the bead the wire is wound, till a sufficient degree of tension is secured. If the wire becomes loose, one or further turns will sufficiently tighten it, or the suture can be relaxed, if it be thought desirable. With a piece of sheet lead, a few beads, a box of matches, and some silver wire, anyone may get ready such sutures with

FIG. 68.—Arrangement of Stitches of Relaxation, of Approximation, and of Coaptation to Close Wound after Removal of Mamma and Axillary Glands (*Cheyne*).

very little trouble. The arrangement and function of the button stitches of relaxation is well shown in the accompanying illustration from Cheyne's "Antiseptic Surgery." (Fig. 68.)

In conclusion, it will be well to repeat that while in different wounds different conditions calling for differing devices for obtaining apposition of the divided surfaces may be found, the great principles will always be the same, and must each be regarded, if the best result possible is to be obtained. These principles are embodied in the three words, *relaxation*, *approximation*, and *coaptation*. When these have been secured, the next duty of the surgeon in the treatment of a wound is to protect the injured parts from disturbance of every kind till repair is complete.

CHAPTER X.

PROTECTION AGAINST DISTURBANCES OF HEALING—ANTISEPTIC DRESSINGS.

Cotton Wool—Borated—Salicylated—Carbolated—Sublimated—Iodoformized—Bismuth—*Gauze*—Carbolated—Iodoformized—Naphthalinated—*Lint*—*Tow*—Oakum—Naphthalinated Oakum—*Jute*—*Turf-Mould*—*Charcoal*—Aluminated Charcoal—*Sand*—Sublimated Sand—*Coal Ashes*—*Sawdust*—*Wood-Wool*—*The Protective*—*The External Impermeable Envelope*—*Bandages*—*The Method of Lister*—*The Iodoform Dressing of Billroth*—*Esmarch's Turf-Mould Dressing.*

In the further history of a wound, it will be necessary that protective dressings be applied, by which it shall be kept from septic infection, from direct mechanical violence, and from motion, and by which also the compression and warmth needed to promote nutrition shall be maintained, until healing is complete.

Septic infection is to be guarded against by covering the part with soft and absorbent materials that will receive and keep aseptic the discharges that drain away from it, and that will purify from septic particles the air that passes through them to the wound. For this purpose many substances may be found useful. Among those more commonly employed are cotton-wool and loosely woven cotton cloth, gauze and lint, tow, jute, turf-mould, charcoal, sand, and sawdust. To the natural absorbent properties of these materials it is necessary only to add the presence throughout their substance of a sufficient amount of some antiseptic material to destroy or to render inert any septic germs that may be brought in contact with it. Materials thus prepared constitute *antiseptic dressings*, the preparation of the more important of which will next demand attention.

ANTISEPTIC DRESSINGS.

Cotton Wool.—Ordinary cotton wool should first be purified and rendered hygroscopic by washing it in an alkaline solution and drying. It is thus prepared on a large scale by different manufacturers in this country

and sold as "absorbent cotton." Its preparation for a wound dressing is completed by charging it with boracic acid, salicylic acid, carbolic acid, iodoform, corrosive sublimate, or other antiseptic.

Borated Cotton.—Hot water dissolves fifteen per cent. of its weight of boracic acid, but on cooling precipitates all but four per cent. If the cotton be treated with an equal weight of a saturated hot solution of boracic acid and then dried, it will remain permanently charged with fifteen per cent. of the antiseptic substance, which is a desirable strength to have to insure its antiseptic properties. Borated cotton thus prepared has the acid intimately incorporated into the substance of its fibres and is free from loose particles of the crystals lying among its meshes.

Salicylated Cotton.—This is usually made of two strengths, 4 per cent. and 10 per cent. Salicylic acid requires 300 parts of cold water for its solution; boiling water dissolves it in the proportion of 1 to 25, but much of a given quantity of the acid is volatilized by the heat of such a solution, making its permanent strength unreliable.

Alcohol takes it up in large quantity, and a dilute spirit makes the best menstruum with which to charge a dressing. As the fine crystals deposited in the interstices of the wool are liable to shake out, a small proportion of glycerine should also be added. The following formula will insure the preparation of the 10 per cent. strength:

Glycerine	2	parts by	weight.
Water	100	"	"
Alcohol	20	"	"
Salicylic acid	2	"	"
Cotton wool	20	"	"

The solution of the acid having been made in the menstruum, with the aid of very gentle heat, the mixture should be placed in a flat vessel, in which the wool should be laid in layers, each being thoroughly saturated before the next is superimposed. When the whole mass has thus soaked for about ten minutes, it is turned upside down, the layers taken off in the order that they were put on, and laid aside to dry, flat, and in a warm room. The antiseptic properties of the wool may be still farther increased by dipping a thin layer of it in a ten per cent. solution of the acid in glycerine, applying this first to the wound, and over this a thick layer of the dry salicylated wool sufficient to extend widely beyond on all sides.

Carbolated Cotton.—Cheyne mentions a carbolized wool prepared by soaking pure cotton wool in a one per cent. solution of carbolic acid in ether, the cotton to be then dried and used immediately. Its use is restricted on account of the volatility of the agent, and on account of the superiority of the gauze preparation of the same agent.

Sublimated Cotton.—Corrosive sublimate may be diffused through cotton by saturating it in an alcoholic solution of not more than one-half of one per cent. strength. A stronger solution should not be used lest irritation of the skin be produced, resulting in eczema and bullæ. The following formula is recommended by Kümmell:

Alcohol	449 parts.
Glycerine	50 parts.
Corrosive sublimate	1 part.

Saturate the cotton, and, having passed it through a clothes-wringer, expose it to dry.

Iodoformized Cotton may be prepared by soaking the wool in an ethereal solution of iodoform, as follows:

Iodoform	50 parts.
Ether	250 "
Alcohol	750 "

and permitting the fluid to evaporate, or, extemporaneously, by rubbing the powder into the cotton, and shaking out the surplus.

Naphthalinated Cotton may be obtained by making a saturated solution of naphthalin in benzine, and steeping the wool in it for a short time. By exposing it in thin layers for a short time, the benzine evaporates perfectly, and leaves the wool charged with the antiseptic.

Bismuth Cotton.—The subnitrate of bismuth should be finely powdered, and then gradually and very intimately triturated with water, in proportions to make a ten per cent. emulsion, in which the cotton may be dipped, as needed, and used at once after expressing the fluid.

Cotton wool may be sufficiently charged with any of the antiseptic powders for many purposes by simply rubbing into the meshes of the wool, at the time it is to be used, the dry fine powder.

Gauze.—Loosely woven cotton cloth is more largely used as an absorbent dressing for wounds than any other material, and is technically known

as "gauze." It is the foundation of the great mass of the antiseptic dressing introduced by Mr. Lister, who first mentioned it in the *British Medical Journal* for January, 1871. The cloth should first be prepared by boiling it in a weak solution of carbonate of soda and chloride of lime, to thoroughly cleanse and disinfect it. This may be done in an ordinary wash-boiler. The cloth is then dried, when it will be found to have become much more absorbent than before. Thus prepared, it may be impregnated with various antiseptics, and kept for use.

Carbolated Gauze.—Gauze impregnated with carbolic acid is the material generally employed by Mr. Lister as a dressing to guard against the entrance of causes of fermentation into a wound after an operation, and is to be provided whenever the so-called Lister dressing is to be applied. Carbolated gauze cannot be kept for any length of time without deterioration, by reason of the evaporation of the carbolic acid. It cannot be kept in permanent store. Hence only that which has recently been prepared should be used. While for general use by the surgeon in private practice who desires to have by him a preparation of gauze that may be drawn upon for occasional dressings from time to time, some other and more stable antiseptic is required. A great many different ways of preparing gauze have been published, but, on the authority of Mr. Cheyne,[1] Mr. Lister's colleague and assistant, none are so good as the following, which can be used in any hospital, and which was recently employed during the Russo-Turkish War for making fresh gauze in camps. The materials to be used are:

Crystallized carbolic acid	1 part.
Common resin	4 parts.
Paraffin	4 parts.

These materials are to be mixed together and added to an equal weight of the cleansed gauze. The technique of the charging process is as follows:

The paraffin and resin are first melted together in a water-bath, after which the acid is added, and blended by stirring. The object now is to diffuse this melted mixture equally through the cotton-cloth, and for this purpose two things are requisite, viz., that the cotton be at a higher temperature than the melting-point of the mixture, and that it be subjected to moderate pressure after receiving it. The cloth, a yard wide, is cut into

[1] Antiseptic Surgery, p. 63.

six yard lengths, and these having been folded so as to be half a yard square, are placed in a dry hot chamber, formed of two tin boxes placed one within the other, with an interval to receive water, which is kept boiling by fire or gas beneath, the upper edges of the boxes being connected and provided with an exit-pipe for the steam. There is also a glass pipe arranged as a gauge of the amount of the water, and the chamber has a properly-fitting lid. The bottom of the chamber is strengthened with an iron plate, to enable it to bear the weight used for compressing the gauze when charged. There is a piece of wood about two inches thick, nearly fitting the chamber, covered with sheet lead, so as to make it about as heavy as a man can lift by means of two handles in the upper surface. The weight is heated along with the cotton, and is put first into the chamber so as to leave the cotton loose for the penetration of the heat, which occupies two or three hours. The cotton, when heated, is taken out of the chamber along with the weight, and placed in a wooden box to protect it from the cold. (It would be better to have a second hot chamber for this purpose, since in cold weather the cotton is apt to be too much cooled, in spite of the protection of the wooden box.) The heated gauze is then at once charged with the melted mixture of carbolic acid, resin, and paraffin, in quantity equal to the weight of the cotton fabric (or slightly less); and in order to diffuse the liquid as equally as possible, it is sprinkled over the gauze by means of a syringe with a number of minute perforations in its extremity, the body of the syringe and the piston-rod having each a wooden handle to protect the hands of the workman from the heat. The syringe is constructed to hold half the quantity of the mixture required for charging one piece of cloth. One folded piece being placed at the bottom of the hot chamber, its upper half is raised and turned aside, and one syringeful is sprinkled over the lower half. The upper half is then put back into position and another syringeful thrown on. The same process is repeated with all the other pieces of gauze, after which the weight is put into the chamber to compress the charged cotton, and the lid applied. An hour or two are then allowed to elapse, to permit the complete diffusion of the liquid, when the material is fit for use.

In this gauze the carbolic acid is the only active agent; the resin is used to prevent the acid from being washed out too soon by the discharge, while the paraffin is employed to lessen the adhesiveness of the resin. The gauze ought to be kept in a tin box, closing tightly, to prevent evaporation of the carbolic acid.

An efficient gauze may be prepared according to the formula of von Bruns, by taking

Carbolic acid	10 parts.
Resin	40 "
Castor oil	8 "
Alcohol	200 "

The resin, powdered, is to be slowly added, with constant stirring, to the alcohol. When the solution is complete the carbolic acid and the castor oil are likewise stirred in. In place of the castor oil, glycerine or melted stearine may be used, the quantity to be used being of equal weight with the acid. The alcohol, also, may be replaced by benzine, as a solvent, and the expense of the preparation be much reduced. The gauze is to be simply soaked in this mixture, being well kneaded to secure its uniform diffusion, and then hung up to allow the spirit to evaporate. It will be dry enough to be ready for use or storing in from five to ten minutes. The whole operation demands neither much time nor skill, nor any particular apparatus. Gauze thus prepared contains about nine per cent. of carbolic acid.

In order to make the gauze dressing more reliably antiseptic, the layers of gauze which go next the wound should be dipped in a watery solution of carbolic acid, 1 to 40, immediately before being applied.

Carbolated gauze that has been used may be washed and recharged with the carbolic acid mixture. It may then be used again.

Iodoformized Gauze may be prepared by roughly rubbing the crystals into the meshes of the cloth. Gauze thus prepared constitutes the ordinary "absorbent iodoform gauze" of Billroth. In preparing it the loosely crumpled gauze should be put into a clean receptacle—a wash-basin rinsed out with carbolic lotion—and plentifully sprinkled, by means of a pepper-box, with the iodoform powder. This should then be worked in with the hands until the whole of the gauze is uniformly yellowed by the powder. Then the excess of the iodoform is to be gotten rid of by shaking, after which it is ready for use. It should be kept in sealed flat glass jars. The amount of iodoform retained by the gauze after the shaking will be from ten to twenty per cent. An ounce of iodoform will impregnate thus between four and five yards of gauze.

This form of gauze may be applied directly to all wounds, except those

in the cavity of the mouth. It absorbs very readily, does not endanger retention, does not irritate like carbolic gauze, and does not readily provoke iodoform intoxication.

An "adhesive gauze" may be prepared by soaking the gauze in an alcoholic solution of resin, to which glycerine is added, and dusting the iodoform upon the sticky surface left after it has been wrung out and half dried, just as in the preparation of the absorbent gauze. For priming the gauze the following formula is used:

Resin	100 parts.
Alcohol (95 per cent.)	1,200 "
Glycerine	50 "

Nearly four times as much iodoform is retained by this gauze as by the unprepared fabric. It is of especial value in dressing wounds in the cavity of the mouth, and for application as a compress upon surfaces from which parenchymatous hemorrhage is taking place.

Naphthalinated Gauze.—Five yards of gauze may be charged with naphthalin by using the following mixture (Fowler):

Naphthalin	1 ounce.
Paraffin	2 ounces.
Glycerine	2 ounces.
Alcohol	2 ounces.

The paraffin is first melted. The glycerine and alcohol are then mixed together and added to the melted paraffin; lastly, the naphthalin is stirred into the mixture, which is kept heated and well stirred until the latter is all dissolved. The gauze is dipped into the mixture while the latter is hot. It is then passed immediately between the rollers of a common clothes-wringer to squeeze out all the superfluous fluid. After a few minutes' exposure to allow evaporation of the alcohol, it is ready for use. It should be kept in closely covered tin cans.

Another method is to make a saturated solution of naphthalin in benzine, in which the gauze is soaked for a few hours for a day or two. The material is then hung up on a line to dry until the benzine has all evaporated (Park).

A solution may likewise be made of the naphthalin in four parts ether,

to which an equal quantity of alcohol is added (Fischer), in which the gauze may be dipped.

Lint may be prepared in any of the ways that have been described as applicable to cotton-wool.

Tow.—Flaxen or hempen fibres may act as substitutes for the cotton, and may be treated in the same ways. They are inferior in absorbent qualities, and are less soft in texture than the cotton. Impregnated with tar they form *oakum* which forms an excellent wound-dressing in many conditions, but it has only feeble antiseptic properties. Oakum may be charged with other antiseptics in addition to the tar, and be of especial value as a cheap material to form the outer layer of dressings. Its fibres are too harsh to make it a desirable substance to place in immediate contact with a wound.

An excellent dressing can be quickly extemporized from the prepared oakum, known as "marine lint," and naphthalin, by picking the former into loose masses and sprinkling it over with the latter and then rubbing the antiseptic well into the meshes of the oakum. The tar in the oakum causes the naphthalin to adhere firmly to its fibres and in sufficiently large quantities to answer all the purposes of a rigid antisepsis (Fowler).

Jute has been largely used as a wound-dressing on account of its cheapness and great absorbent power. This is a vegetable fibre obtained chiefly from Bengal, and brought in large quantities to the New York market, where it is used in the manufacture chiefly of mats and coarse woven stuffs. It is one of the most cheaply raised and prepared of all fibres. The best qualities, which alone are suitable for surgical use, have a clear white, yellowish color, with a fine, silky lustre. The fibres are soft and smooth to the touch, and are fine, long, and uniform. They are composed of from thirty to one hundred fibrillæ, flattened in external shape, and tubular in the centre, which well adapts them for the absorption and retention of an antiseptic medium.

Jute dipped in a ten per cent. solution of carbolic acid in spirit dries quickly and retains a large quantity of carbolic acid, as much as six to eight per cent. for ten or twelve days.

Jute may be impregnated with various antiseptics in the same ways as have already been described for cotton-wool. It should be cleaned before impregnation. The fluids that drain out of it, when it is hung up to dry, should be again poured over it, until they are all taken up.

Turf-Mould.—The dust or mould obtained from carbonized turf—peat

—has been used as a wound-dressing with great advantage by Esmarch and Neuber,[1] of Kiel. The advantages claimed for it are these :

1. A given quantity of the mould takes up more fluid than jute, gauze, or cotton wool. If it be lightly moistened, its absorbent power is still increased ; wounds remain perfectly dry under it. 2. It possesses a great power of absorbing products of decomposition of organic substances, and hence prevents the same from occurring, and acts even in the unprepared form. 3. The moistened mould is a very soft but still elastic substance, so that it is easily placed in the required position in the bags before applying them to the inequalities of the body. 4. It is the cheapest of known antiseptic dressings, one pennyworth sufficing for a dressing, and will be more so when it is found that the preparation with some antiseptic can be left out. 5. It makes a very suitable pad for all purposes when enclosed in gauze.

To increase its antiseptic properties, the mould may be impregnated with carbolic acid, chloride of zinc, or iodoform.

Charcoal.—Powdered charcoal, by its quality of absorption and filtration of fluids, is well fitted for a wound-dressing. It is possessed of antiseptic properties in its natural state, and is one of the oldest disinfectants used in medicine.

Aluminated Charcoal.—Kümmel recommends the addition of acetate of alumina to charcoal to increase its antiseptic properties. It is to be prepared by first baking the finely powdered charcoal for several hours and then mixing it with powdered aceto-tartrate of alumina in the proportion of

Charcoal	7 parts.
Aceto-tartrate of alumina	3 parts.

If the mixture contains equal parts of the ingredients it produces a slight irritation of the fresh wound-surface, and even in the present proportions this irritation sometimes occurs. After a few days, however, the irritation disappears, giving place to a healthy granulating surface. A smaller proportion of the alum would prevent the irritation without diminishing the antiseptic properties of the mixture.

Wound cavities, where primary union is impossible, may be filled in with this aluminated charcoal and covered with a few layers of gauze and any impermeable material. The first dressing may often be allowed to

[1] *Erfahrungen über Iodoform- und Torfverbände in der chir. Klinik des Herrn Esmarch.* By Dr. G. Neuber, *Archiv für Klinische Chirurgie*, 1882, Band xxvii., p. 757.

remain one to two weeks without a change. In small wounds healing takes place as under a scab.

Sand.—A fine quality of purified sand, common white quartz-sand, has also been used with great advantage in the General Hospital of Hamburg (Kümmell) as a wound-dressing. It is easily obtained, is cheap, and can readily and quickly be made aseptic. After having been passed through a fine sieve, it should be heated several hours in a covered pan. Directly after cooling it should be mixed with an ethereal solution of corrosive sublimate and be afterward preserved in glass-stoppered bottles.

Sublimated Sand.—An efficient and reliable antiseptic sand may be made according to the following formula:

Corrosive sublimate	10 parts.
Ether	100 "
Sand	10,000 "

—150 grains of the sublimate being sufficient to impregnate 20 lbs. of sand. It may be used, like other antiseptic powders, to fill wound cavities, being covered with sublimated gauze over which a gauze bandage is fastened. The use of an impermeable outer covering is objectionable, as thereby desiccation is prevented, and healing under a scab impeded. In consequence of the fine grain of the sand, it may be instilled into narrow fissures and recesses. The dressing may remain in place for weeks till healing has taken place, by simply renewing the layers of gauze as they become impregnated with the wound-secretions. Before replacing the layers of gauze, the wound should be irrigated with a solution of the sublimate, and the sand, where missing, renewed. The sublimated sand promotes in a marked manner dryness in a wound. This it does by decreasing the amount of the secretions and by absorbing whatever moisture may occur. Frequently it was found, upon removal of the firmly dried crust of sand, that the wound had healed as under a scab. Rarely do particles of sand remain in the healed wound. If they do, they are harmless. The sand may also be used as a dressing for wounds that have been sutured for primary union, a light layer of lint or wool being first laid over the line of suture.

Coal-Ashes.—Finely sifted coal-ashes, on account of their lightness, inorganic nature, and absorbent properties, are adapted for wound-dressings. Their chemical composition consists of elements more or less antiseptic in their nature, which may be increased by wetting them with an antiseptic

solution.[1] Kümmell has substituted sublimated ashes for sand in many instances. According to this surgeon, the best ashes for the purpose consist of the fine and light powder, called flying ashes, which settles in large quantities behind the fire-boxes of steam boilers. Cushions filled with this latter substance form admirable means of compression, being soft and pliable and readily adapting themselves to the shape of the parts to which they are applied. Cushions filled with the prepared ashes for ordinary purposes of wound-dressing are moistened just prior to being used, in order to facilitate their absorbent action. It is recommended to use several small cushions rather than one large one in the dressing.

Sawdust.—As a cheap and readily obtained absorbent dressing, bags of sawdust, impregnated with iodoform, corrosive sublimate or carbolic acid, have been used in the New York Hospital and have answered well.[2]

Wood-wool.—From Professor Bruns, of Tübingen, we receive a fresh addition to our means for carrying out the after-treatment of wounds, in the form of a preparation which he calls "wood-wool," and which he recommends to surgeons.[3] Fine-grained wood in the form of splinters and shavings, such as are largely employed in paper factories, according to Bruns, is the kind of material to be used in preparing the dressing which is called wood-wool. Pine wood is preferred, and especially the pinus picea, which is poorer in resin and of coarser grain as compared with the wood of other pines and firs. The further preparation of the wood shavings and splinters consists in their reduction to a state of finer division by being rubbed through a wire sieve, then dried, and finally impregnated with various antiseptic substances. That considered best is a half per cent. of corrosive sublimate and ten per cent. of glycerine (the percentage apparently referring to the ratio between these substances and the wood-wool). The advantages of such a dressing are believed to be manifold. Compared with ashes and turf it is absolutely clean, fresh, and of white color, and is

[1] Kümmell gives the following as the average composition of the ash of English coal:

Sulphuric acid	8.38
Phosphoric acid	1.18
Silicic acid	61.66
Lime	2.62
Magnesia	1.62
Oxide of iron and alumina	24.42

[2] R. F. Weir: Dressings for Wounds, New York Medical Journal, January 6, 1883, p. 6.

[3] *Berl. Klin. Woch.*, 1883, No. 20.

soft and pliable like ordinary wool, and withal of extraordinary cheapness. It possesses, in virtue of its contained resin, ethereal oils, certain antiseptic properties, and is so easily adapted to the wounded parts, and of such elasticity, that a uniform and equable pressure is easily obtained. Its principal property, however, is its extraordinary power of taking up fluids; in this it excels all other forms of dressings; it absorbs twelve times its own weight of fluid, so that ten grams of dried "wood-wool," after complete saturation, weigh one hundred and thirty grams. Simple sawdust absorbs only three or four times and a half its weight of water, ashes only nine-tenths, and sand only four-tenths. This dressing has been in use by Bruns for half a year, and he has every reason to be greatly satisfied therewith. With the exception of one case of erysipelas, no secondary accidental wound diseases were met with.

The Protective.—Whenever the direct contact with the wound surfaces of these dressings would chemically or mechanically irritate them, as is especially the case with those that are impregnated with carbolic acid, it is best to apply, over the exposed wound surface, a layer of some aseptic neutral and unirritating substance as a protective, over and around which the antiseptic dressings shall be placed. Such a layer will be of use also in preventing the dressing from sticking to the wound, and in preventing the formation of scabs, and the consequent possible retention of the discharges. The material so used is, in general parlance, distinguished by the technical name of the *Protective*.

The special material employed by Mr. Lister, in connection with his carbolic acid dressings, consists of oiled silk coated with copal varnish. When this is dry a mixture of one part of dextrine, two parts of powdered starch, and sixteen parts of cold watery solution of carbolic acid (1 to 20), is brushed over the surface. The rationale of this method of preparation is the following (Cheyne): Oiled silk alone is better for the purpose of a protective than gutta-percha tissue, because carbolic acid does not so readily pass through it. It does, however, do so, and therefore copal varnish, which is almost absolutely impermeable to carbolic acid, is added. As, however, the fluid collects on this as on a duck's back, leaving intervals between each drop on which dust may fall and escape the action of the acid, the dextrine solution is added, and the result is that when moistened the whole surface of the protective remains uniformly wet. The use of the carbolic acid in the dextrine solution is not to add any carbolic acid to the protective, but because it is better

than water for enabling the dextrine to adhere to the varnished oiled-silk. For the same reason the powdered starch is added. The original carbolic acid flies off very quickly from the protective, leaving a material containing no antiseptic in its substance.

This protective should always be dipped in an antiseptic solution (carbolic acid 1 to 40, or corrosive sublimate 1 to 1,000) before being applied to the wound surface.

Although the dextrine-cōpal-oiled silk of Lister is a superior form of protective material, it is not indispensable, and, when it cannot be conveniently obtained, may be substituted with very good effects by ordinary rubber tissue.

When less irritating agents than carbolic acid, as salicylic and boracic acids, are used for impregnating the dressings, the protective is of less importance. The powder dressings, as turf-mould, iodoform, naphthalin, bismuth, etc., are best applied without the intervention of a protective.

Cheyne calls attention to the frequent error of putting on too large a piece of protective. There is nothing antiseptic in its substance, and it protects the discharge beneath it from the action of the antiseptic in the other dressing materials. Therefore if at any part it projects beyond or comes close to the edge of the dressing, it allows the causes of putrefaction to spread inward beneath it, and prevents the antiseptic from acting on this putrefying discharge. It is therefore a very good rule, he remarks, having covered the wound with sufficient protective, to look on this protective as a wound, and to be as careful in having the gauze dressing overlap it in all directions as if it were itself the wounded surface. Where there is very little space for overlapping, no protective ought to be applied. It is better to have somewhat slower healing than to have putrefaction spread into the wound.

External Impermeable Envelope.—For the purpose of arresting the evaporation of the antiseptic when it is volatile, and to prevent the secretion which soaks through the dressing, if it should come directly to the external surface, from being there exposed to atmospheric influence, and becoming septic, in close proximity to the wound, the dressings may be enveloped in some thin impermeable material. This is of special importance in carbolic acid dressings on account of the volatility of the acid and the excessive serous oozing which it provokes. The material used by Mr. Lister is composed of cotton cloths with a thin layer of india-rubber spread on one side, called *Macintosh* cloth. In its use care is to be taken that the

side on which the rubber is spread should go next the wound, and that it should be without a rent, pin-hole, or other defect. The presence of a small opening more or less completely neutralizes the object and endangers the failure of the antisepsis. As less expensive than the Macintosh cloth, rubber tissue, waxed paper or paraffin paper are used as substitutes,[1] but they are less reliably impermeable than the Macintosh. The same piece of Macintosh, if thoroughly cleaned and disinfected, may be used several times.

The use of an impermeable external envelope is open to the very serious objection that it keeps the skin underneath it moist from retained perspiration, and by its moist warmth promotes the activity of whatever sources of putrefaction may escape the antiseptic cares that have been taken. It tends to envelop the wound in putrefiable material so that the more frequent and more copious application of antiseptics is required to secure continued freedom from sepsis. With the introduction of less volatile and less irritating substances as antiseptics than carbolic acid it has been possible to abandon the use of any impermeable covering.

Bandages.—For the purpose of adjusting and retaining the dressings in place, bandages of various widths are required. If the case requires their direct application upon the deeper parts of the dressing, they should be made of antiseptic gauze. Gauze that has been primed with the resin mixture (page 189) has the advantage that each turn of the bandage made of it adheres to the previous one, giving additional security to the dressing. If carbolic gauze is used, it should always be dipped in carbolic lotion, 1 to 40, immediately before being applied.

To fasten down the margins of the dressing in places where the movements of the body tend to loosen the dressing, and thus to allow air to penetrate beneath its margins, elastic bandages of ordinary elastic webbing, or of pure rubber tissue (Martin's bandage) serve an excellent purpose and in some regions, as the groins, axilla, neck, and head, are indispensable. These bandages are most manageable in short lengths, and should vary in width from one to two and a half inches, according to the size of the dressing, or the region of the body to be dressed. They should not be put on too tightly, but stretched just firmly enough to keep everything

[1] Codman & Shurtleff, of Boston, furnish these various materials at the following prices: Macintosh cloth, 1 yard wide, per yard, $1.50; heavy gutta-percha tissue, 32 inches wide, per yard, $1.00; thin gutta-percha tissue, 32 inches wide, per yard, 50 cents; paraffin paper, 32 inches wide, per yard, 6 cents.

secure against the movement of the part, or the shifting position of the patient (MacCormac).

APPLICATION OF THE DRESSINGS.

The Method of Lister.—As the method perfected by Mr. Lister was the first in which the indication for protecting wounds from contamination by septic dust, and for keeping their discharges free from putrefaction was accepted as the chief end of treatment, and was successfully accomplished, the details of the arrangement of the dressings adopted in this method for securing continued protection after the arrest of the hæmorrhage, the cleansing of the wound, its drainage, and the apposition of its surfaces had been accomplished, claim the first mention. The following is Cheyne's description of the details of the application of these dressings ("Antiseptic Surgery," pp. 87–93):

The dressing employed is the carbolic gauze; and to prevent the irritation of the healing edge of the wound by the carbolic acid, a piece of protective is interposed between the gauze and the wound. This protective is cut a little larger than the wound, and it is well to cover the buttons with a little bit also, in order to prevent the threads of the gauze from becoming entangled in them. This protective need not extend over the orifice of the drainage-tube, as its essential object is to protect the healing part from the irritation of the carbolic acid. Outside the protective a piece of gauze wet in the carbolic lotion (1 to 40) is applied so as to overlap the protective in all directions. The reason for this is that dry gauze is apt to receive dust on its surface before being used, while at the ordinary temperature of the atmosphere but little carbolic acid is given off from the gauze, certainly not enough to destroy immediately the activity of the septic particles in the dust. But if the piece of gauze applied next to the protective be moistened in the 1 to 40 solution, this dust is at once deprived of septic energy, and we apply over the wound a layer of pure and powerfully antiseptic material. The piece of wet gauze and the protective go by the name of the deep dressing (Fig. 69). This deep dressing may, in some cases, and more especially where catgut stitches and catgut drains are used, be left for several days undisturbed. If the deep dressing be thus left on, it must be remembered that the deep piece of gauze loses all its carbolic acid very soon, and that, therefore, it must be treated as a wound—*i.e.*, in renewing the dressing this deep part must be

overlapped in all directions by a piece of wet gauze, and that again by a dressing of suitable size.

Having arranged the deep dressing in a suitable manner, any hollows which exist in the neighborhood of the wound are filled up with carbolic gauze, and special masses of this material are placed where the greatest amount of discharge is expected. Outside this a large gauze dressing, consisting of a piece of gauze of sufficient size folded in eight layers, beneath the outer layer of which is placed a piece of macintosh cloth, is applied. The size of this dressing varies according to the amount of discharge expected, but in all cases it must extend well beyond the deep

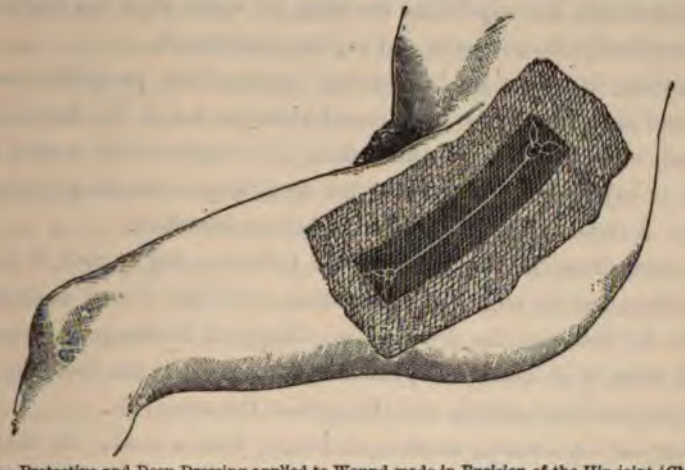


FIG. 69.—Protective and Deep Dressing applied to Wound made in Excision of the Hip-joint (*Cheyne*).

dressing in all directions. This dressing is fixed on with a suitable bandage of gauze or ordinary cheap muslin. The dressing is pinned round its edge to the bandage. Care must be taken not to put pins through the macintosh at any part except at its edge. To prevent the edge of the dressing from becoming separated from the skin, and air passing into the space thus formed, the edges of the dressing are surrounded with an elastic bandage, put moderately on the stretch, its general arrangement varying with the situation.

As a rule, the dressing ought to be changed entirely on the following day, the deep part as well as the superficial. It is well to change the deep dressing in order to see that none of the stitches are too tight, and that the drains are acting properly. After the first day the deep dressing need not be touched, unless the patient is complaining of uneasiness, or unless the surgeon wishes to see the wound for the purpose of removing stitches

or drain. If the deep dressing is not changed, great care must be taken to have an efficient spray playing over the part.

In changing the dressing the spray is used, and also 1 to 40 carbolic lotion, in which a piece of loose gauze and protective are put before the dressing is begun. The elastic bandage is first removed, and then the patient or an assistant places his hand over the centre of the dressing while the bandage is being cut, so as to prevent the dressing being lifted up and air pumped in. Then the surgeon, having purified his fingers, and having turned on the spray, lifts the edge of the dressing carefully, taking care that the spray passes into the angle between the dressing and the skin. Having removed the superficial dressing, he again dips his fingers, and then removes the deeper parts and exposes the wound.

If nothing is wrong, he immediately applies fresh protective and wet gauze, and then washes the parts round about, as far as the discharge has extended, with 1 to 40 carbolic lotion. The edge of the wound is not washed or exposed to the action of the spray longer than is absolutely necessary. A fresh dressing is applied as before described.

The next dressing takes place on the following day at visit, if there is any discharge at the edge of the dressing, or if the wound feels uneasy. The rule for changing the dressing is: Change if discharge is through at the visit hour, or if there be any other reason for it; if not, leave the dressing till the next day at visit, and then follow the same rule.

Never leave a dressing unchanged longer than a week. By that time most of the carbolic acid has passed off by evaporation, and therefore, if the discharge once came to the edge, putrefaction could spread inward with great rapidity. And it would not be necessary for the discharge to appear at the edge in order to have putrefaction of the wound, for the sweat collecting beneath the dressing permits the multiplication of septic particles in it, and thus they may reach the wound.

The Iodoform Dressing of Billroth.—According to the practice of Billroth, of Vienna,[1] it makes little difference, in most cases, what kind of antiseptic protective material is used for the immediate covering of wounds that can be closed, but on account of its less irritating properties, its effect to diminish secretion, and its more permanent and intense antiseptic power, the iodoform gauze is preferable to the carbolized gauze. The iodoform dressings, however, have their greatest usefulness in wounds that cannot

[1] Hacker: *Anleitung zur Antiseptischen Wundbehandlung nach der an Prof. Billroth's Klinik gebräuchlichen Methode.* Wien, 1883.

be united, in wounds of mucous cavities, and in larger wounds in which processes of decomposition already exist.

Closed wounds.—Superficial wounds, as, for example, in the face, though they have little need of any dressing beyond the scab formed by the desiccation of the slight layer of blood and secretion that collects upon the line of their union, as a matter of security, may be covered with iodoform collodion [1] or iodoform gauze.

In deeper wounds, no iodoform is applied to the wound surfaces, and no "protective" is applied over the line of suture. The advantage of an easy removal of the dressing material from a wound covered by "protective," is surpassed by the advantage of the drying of the secretions as they come in contact with the gauze, and by the more immediate effect of the iodoform upon the secretions as formed. The sutures are made less irritating, also, as evidenced by the fact that suppuration at the points of entrance and exit of the needle, when iodoform is used, is very rare. Directly upon the wound, after its apposition and suture has been effected, from four to six layers of absorbent iodoform gauze are laid, of sufficient width to extend half an inch beyond the margins of the wound. Over this is placed one or more layers of crumpled carbolized gauze, and over all a layer of smooth carbolized gauze, or absorbent cotton, or ordinary purified gauze. The whole is enveloped in a layer of impermeable material, and, at the margins of the dressing, pads of absorbent cotton or gauze are placed so as to afford compresses over the impermeable material wherever special pressure seems indicated. The fixation of the dressing is accomplished by a common roller bandage.

Open wounds.—No other dressing will give such uniformly good results in the treatment of open wounds as the iodoform. Nor is any method of dressing such cases so simple in its application, or requiring such infrequent changes.

Open wounds, after being cleansed, are to be simply filled with absorbent iodoform gauze. In irregular cavities, the first layer of the gauze is cut in strips and introduced into all fissures and compartments; into the remaining cavity layers of gauze are loosely packed till the space is filled to the level of the integument. A double layer of iodoform gauze is then placed upon it so as to extend over the margins of the wound. The dressing is completed by carbolized gauze, impermeable material, and bandages, ex-

[1] Iodoform collodion is a solution of iodoform in collodion in the proportion of 1 part to 10.

actly as in closed wounds, except that no firm compression is to be produced. Healing takes place by granulation with but very little suppuration. The dressing may be left undisturbed for from eight to fourteen days.

It is of the greatest importance that every corner and fissure of a wound be brought in contact with the iodoform gauze.

Change of Dressings.—It is expedient not to permit the dressings to remain unchanged for a longer period than eight to ten days, on account of the eczematous irritation of the skin which the gauze and the retained perspiration is likely to excite, if left unchanged too long, notwithstanding the antiseptic properties of the dressing may be sufficient for a much longer time. After major operations, it is sometimes desirable to change the dressing on the evening of the same day, or the day following, on account of the saturation of the dressing by hæmorrhage. If the oozing is moderate, it may suffice to renew only portions of the dressing the first evening, as the carbolized gauze, cotton, and impermeable material, and defer the complete change until the next day. As long as no secretions appear on the surface the dressing may remain, so that in the treatment of very large wounds that may require three or four weeks for healing, the dressing may be changed only two or three times. In general, however, the dressing will be renewed in six to eight days, the time when the drainage tubes and deep sutures are to be removed. When complete union by first intention is not secured, the drainage tubes must be left in place where suppuration exists, to be gradually shortened before their final removal. In such wounds a change of dressing is rarely required on account of abundant secretions; the gauze adhering to the wound may remain, and it will be only requisite to change the layers of carbolized gauze and of cotton. In cases where, as in compound fractures, it is of the greatest importance, for the formation of callus and for the rest of the part, that the dressing remain as long as possible, it may remain fourteen days or even three weeks, provided no disturbance manifests itself. The openings left by the drainage tubes will require a longer time for closure, and will leave small cicatrices.

A change of dressing becomes *necessary* whenever the temperature rises to 102° F., and above, especially when connected with rigors. It is *desirable* for safety's sake at any time when the dressing is abundantly saturated with blood. When the dressing is changed, the drains should be injected with a stream of water to see that they are not clogged; any

tension of the sutures may be moderated by the removal of some of them. If the febrile disturbances do not disappear, if the secretions increase, assuming a suppurating character, with a bad odor—a rare occurrence—the dressing must be changed every day, or every second day. Iodoform gauze should be used sparingly on account of the danger of the toxic effects of iodoform. In such cases, forming an exception to the general rule, the wound should be irrigated with a strong solution of carbolic acid 1–20, or with a solution of chloride of zinc 1–500. In an ordinary change of dressing, irrigation and pressure to remove détritus is not used.

If, notwithstanding the injections, fever, anorexia, and general weakness remain, it is proof that antisepsis has failed. It becomes necessary then to remove the sutures, open the wound, and fill its cavity with iodoform gauze. If a frequent change of the dressing is imperative, some other antiseptic, as acetate of alumina, must be substituted for the iodoform. After the wound is perfectly pure, the process of healing may be hastened by approximating the edges of the wound by secondary sutures of silver wire, or strips of iodoform or adhesive plaster may be applied.

As a rule, the iodoform gauze should be continued only for two or three weeks, until a good, healthy, granulating surface has formed, the final cicatrization of which will be hastened by the use of zinc or boracic acid ointment.

Esmarch's Turf-mould Dressing.—This is used in the following manner, which has been very successful: Bags of gauze wrung out in 5 per cent. carbolic solution are prepared of two sizes, 5 and 10 square inches respectively. These are filled with turf-mould (or dust), the smaller bag with mould containing 2½ per cent. of iodoform, which is laid on the wound directly, which has been disinfected with either carbolic solution (2½ per cent.), zinc chloride (8 per cent.), or, at most, 45 grains of iodoform. Over this is laid the larger bag, the mould in which is saturated with 5 per cent. carbolic solution. The whole is kept in place by a gauze bandage.

These examples which have been detailed will suffice to illustrate the method of applying practically the principles which will guide the surgeon in the use of any of the absorbent, antiseptic, and protective dressings which have been described. In the chapters on antisepsis, antiseptics, and wound-cleanliness, the indications to be met, and the special properties of various antiseptics have been carefully detailed. The judgment, per-

haps simply the convenience or caprice, of the surgeon will determine the choice of individual applications in many cases. All other things being equal, those applications which are the simplest, the least expensive, the most readily obtained, and which need the least frequent changing, merit adoption for general use. The particular indications which special wounds present will be considered in the chapters devoted to those wounds.

CHAPTER XI.

PROTECTION AGAINST DISTURBANCES OF HEALING—(CONTINUED).

REST.

Position—Compression—Immobilization—Wire-gauze Splints—Plaster-of-Paris Splints—Shells—Encircling Plaster-bandage—Fenestrated—Interrupted—Combined—Change of Dressings—Anodynes.

REST, as nearly absolute as possible, is of great importance in favoring the undisturbed and rapid healing of a wound. This involves protection from motion and from external mechanical violence, the control of muscular spasm, and every means which will tend to insure quietude and comfort in the wounded part. The means by which rest is to be obtained, include Position, Compression, Immobilization, Infrequent and Careful Dressings, and Anodynes.

POSITION.

That position should always be selected which will be comfortable to the patient. An uncomfortable position provokes general restlessness and local muscular spasm. Attention to the comfort of the part cannot be too carefully regarded. This position will always be one in which the parts are relaxed, and the return circulation of the blood to the heart is favored. The limbs, if wounded, should be slightly flexed and elevated. In wounds of the lower extremity this is of more importance, and demands more care in its accomplishment. The foot should be raised to a higher level than the knee, and the knee than the hip; in cases of severe wounds the limb should be swung so that movements of the trunk should not disturb the injured limb. The relations of position to drainage should be kept in mind, and in the arranging of the means for drainage, whenever possible, the drains should be so placed as to be most efficient when the part shall have been placed in the position of the greatest comfort.

COMPRESSION.

Gentle, uniform, and continuous pressure is of great value in promoting rapid repair after injury. It restrains excessive "active hyperæmia," limits effusion, and promotes absorption of effusions already present. When properly applied it prevents muscular spasm, and thus becomes a valuable auxiliary in securing rest to the part. A greater and more methodical application of pressure than is needed for maintaining simple apposition of the separated parts is required to obtain the full power of compression in favoring the repair of a wound. Compression should be smooth and uniform, gentle but firm, while any constriction is carefully avoided. In most cases it may be best effected by surrounding the wounded part with layers of cotton wool, and applying compression with roller-bandages. The wool moulds itself exactly to the limb, and by its elasticity tends to evenly distribute the compression exercised by the bandage and to keep the pressure continuously uniform. In cases of wounds of the limbs the bandage should be applied first at their distal ends, and carried up evenly and carefully over the wounded part, and above it for some distance. The means of compression will also be important elements of the means of immobilization, in the consideration of which the value of the compression itself is apt to be lost sight of. Experience, however, has shown that immobilization without methodical compression is more imperfectly and slowly efficient in promoting repair and delaying wound-disturbances than when both are combined. Perfect quiet and uniform compression are the most conspicuous agents which can reinforce the natural reparative energy of a part.

IMMOBILIZATION.

Immobility is to be secured by the judicious application of splints, pads, and bandages. A splint, whenever applied, should assist in furnishing equable and uniform compression and support, as well as fixation. For this purpose the various forms of plastic splints offer great advantages in many cases in which, as in penetrating wounds of joints and compound fractures, fixation of an entire limb is necessary. Such splints accurately take the shape of the parts, forming a firm mould that encases and fixes the limb without pressing unduly at any one point. As a result such splints are borne with comfort, and thus indirectly contribute still more to the well-doing of the wound. It is unnecessary to attempt to enumerate

the many different materials that in cases of emergency may be used as splints. Wherever a wound may be received some agent that will serve a temporary purpose for immobilization will be found. In lieu of better, bundles of straw or twigs, or layers of folded newspapers may serve an excellent purpose as splints. Upon the battlefield various weapons admit of many most excellent applications as splints. Thin strips of wood, shaped according to the requirements of the part to which it is to be applied, and padded with cotton wool, will always be found to make most excellent splints. There are two kinds of material, however, which from their special advantages as agents of immobilization in the treatment of wounds deserve more extended notice. These are wire-gauze and plaster-of-Paris.

Wire-gauze.—This material is made of wire from one-twentieth to one-tenth of an inch in diameter, woven into a fabric, the meshes of which are from three-tenths to five-tenths of an inch square, or the length of the mesh may be greater than the width. After the gauze is cleaned with acid, it is put into melted zinc, which covers the wires and fastens them quite firmly together where they cross each other, making a firm and strong structure. The material is a common article of commerce, is cheap, is to be found in all hardware shops, and is put to many economic uses. My attention was first called to the value of this material for surgical purposes in 1873 when I entered upon duty as adjunct surgeon to the Long Island College Hospital, where it had been introduced by my immediate predecessor, Prof. J. S. Wight. Its surgical uses have been described by Prof. Wight,[1] as follows: In the first place, the fabric can be cut into any desired shape by a pair of tinsmith's shears. The separate wires may be cut out by a pair of cutting pliers. The pieces of gauze may be bent into any required form by the hands of the surgeon; and when bent it will generally have enough firmness and resistance to keep its form under all ordinary circumstances. It is very light—having the same extent of surface, it is lighter than wood, tin, zinc, or binder's board, used for splints. It ventilates the part to which it is applied better than any other splint material. It is very desirable where irrigation is needed; it is non-absorbent. At any time it can be removed, disinfected, and reapplied with facility. It may be strengthened by fastening to it by small staples light strips of wood. It may be used to strengthen plaster-of-Paris splints, particularly when they are to be fenestrated. The combination of qualities

[1] The Surgical Uses of Wire-cloth. Proceedings of the Medical Society of the County of Kings, January 1881, p. 375.

which have been enumerated—its cheapness, the readiness with which it can be shaped and moulded to a part, its lightness, its non-absorbent qualities, and the perfect freedom with which its open-meshed interstices permit the passage of moisture through it, make it a material of great value for purposes of wound-dressings.

Plaster-of-Paris.—Of the various substances that have been used while in a moist and pliant condition to envelop a part, a firm mould of which they afterward form by hardening, plaster-of-Paris has proved to possess in the greatest degree the qualities needed for common use. It is generally easily and quickly procurable ; it is cheap ; its manipulation is simple ; it quickly hardens and forms a firm and accurate envelope of the part to which it is applied, so as to insure absolute immobility and uniform compression with perfect comfort. It is porous, and so does not prevent the escape of the natural perspiration from the parts covered by it. Fine white plaster (dentist's plaster) that has recently been calcined, is to be chosen for use in making an immobilizing apparatus. If it has been exposed to moist air, it will have absorbed sufficient moisture to prevent its hardening readily and firmly. If fresh plaster is not attainable, the old may be made again fit to use by reheating it. For this purpose it will simply be necessary to heat it in an iron pan over a good fire for half an hour, or until it ceases to "bubble."

The part to be immobilized should be wrapped with a layer of cotton wool—sheet wadding—or in default of this, by strips cut from a woollen blanket. A stout thread, or bit of cotton twine, wound in a rapid spiral over this preliminary layer of cotton or blanket, will be convenient in keeping them in place while the plaster is being applied.

Three different methods may be used in applying the plaster.

One method is to cut strips of coarse blanket flannel, crash towelling, or similar strong, open-meshed material, into suitable lengths and shapes, so that they will partially envelope the part like a cuirass, as in Figs. 72 and 73, and dip them into plaster-of-Paris when mixed with water, so as to have the consistency of a rather thick cream. The cloth strips thus impregnated are then applied to the limb, and while the plaster is still plastic are secured to the limb by roller bandages. As many layers may be applied as may be thought necessary to give the requisite strength to the splint. The Bavarian splint (Figs. 70 and 71) is made by fastening two pieces of such cloth together by a row of stitching down the centre, and pouring the plaster-cream between the pieces.

When it is to be employed the layers of cloth should be applied to the limb so that the row of stitching is at the nether side of the limb ; then the innermost layer is brought up about the limb and smoothly adapted to it, its edges, meeting in front, being secured with pins temporarily. Then the plaster is poured thickly over the outer surface of this layer, and

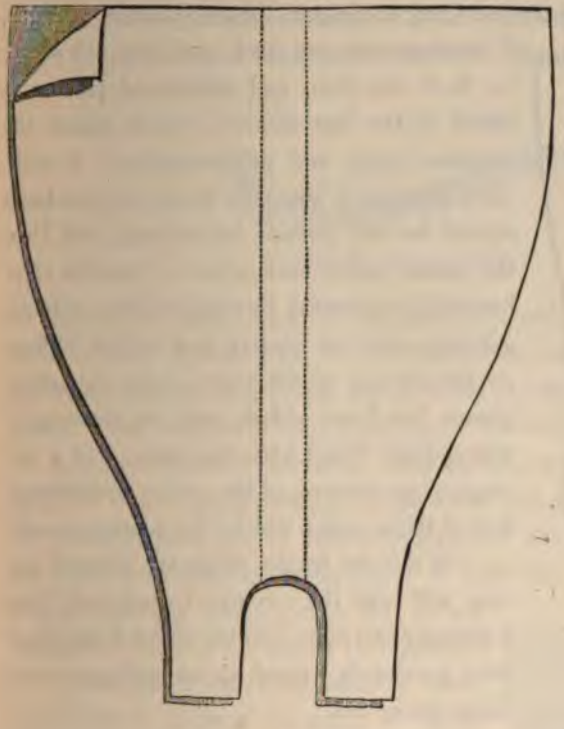


FIG. 70.

FIG. 71.

Fig. 70.—Pieces of Cloth as shaped for applying the Bavarian Splint to the Leg (*Esmarch*).
Fig. 71.—The Bavarian Splint applied.

upon the inner surface of the outer layer, being uniformly spread over them by the hand of the surgeon. The outer layer is then to be brought up to the first, and after having been properly moulded to the limb by the hand, is confined by a roller bandage until the plaster has hardened.

It will then be found that there has been made a splint consisting of two lateral halves, connected together behind by a cloth hinge, which permits the two halves of the splint to open like a book and expose the injured parts. When anterior and posterior strips (Fig. 72) are used, there results two accurately fitting shells (Fig. 73) either one of which can be

lifted off to facilitate inspection of the part, while it is still supported by the other. A great variety of forms of splints, as needed for special locations and injuries, can be made from strips of cloth and plaster after this method.

The following practical directions for the preparation of these splints are by MacCormac ("Antiseptic Surgery," p. 188), and are worth heeding: "Dressers seldom know the best way to prepare plaster-of-Paris for use. It is often made too thick, and sets too soon; or, it is too thin, and additional plaster is added at the last moment, which makes the mixture lumpy and unmanageable. A sufficient quantity of water for the purpose in hand should be first poured into a basin, and then the plaster lightly shaken into it, handful after handful, or spoonful by spoonful, but without stirring, until the plaster just begins to float on the surface of the water; then enough of plaster has been added, and, on stirring, it will quickly blend with the water, and a homogeneous mixture, of the proper consistence, that of thick cream, will be the constant result.

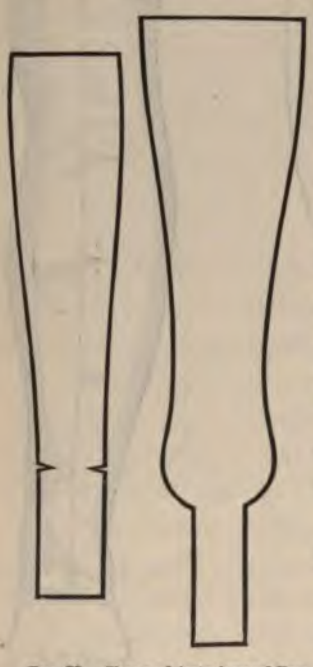


FIG. 72.—Shape of Anterior and Posterior Flannel Strips, for application to Lower Limb from Midthigh to Toes (*MacCormac*).

"In this the flannel strips are dipped, and they will take the mixture better, and form a stronger and more durable splint if they have been previously wetted, all superfluous water being wrung out."

The second method consists in the application of roller bandages whose fabric is saturated with the plaster. These bandages are previously prepared by rubbing into their interstices the dry plaster; when required for use, the bandages, made into loose rollers, are immersed in warm water for a short time, until bubbles of air cease to escape, when they are at once applied. To reinforce the bandages, plaster-cream can be smeared over them after they have been applied. Ordinary muslin rollers are not well adapted for use as plaster bandages. A more open-meshed and absorbent fabric is needed. The experiments of Dr. Nelson,[1] of Boston,

[1] Plastic Splints in Surgery. Annals of Anatomy and Surgery, 1882, v., p. 170.

have shown that the cheap bleached cotton-cloth used for printed calico, if used before it has received the dressing, is a superior fabric for plastic uses. It is then free from oil and is absorbent. It has the right texture to take up plaster and retain it. It gives the maximum of strength, and when applied is very durable.

The impregnation of the meshes of the cloth with the plaster with the hand or knife produces an imperfect and uneven result, while it is at the same time a dirty and disagreeable process. The simple method suggested

FIG. 73.—Anterior Leg Splint.

by Esmarch ("Handbook," p. 44) affords a more satisfactory result in a most convenient manner. It is to put the end of the bandage through a slit in an upright board (Fig. 74), in front of which the plaster-of-Paris is placed; the bandage is then rolled up in this heap with the fingers.

The third method consists in applying bandages of open-meshed fabric, as gauze or mosquito-netting, to the limb, and then smearing them with the plaster-cream, adding successive layers of the bandage and of the plaster until a sufficiently strong splint is built up. A very light, firm and tough splint can thus be built up. It is a method to which I am myself very partial.

FIG. 74.

Where there are open wounds, openings must be made in the splint by which ready access to the wound can be secured and free escape of the secretions may take place (Fig. 75). These are best made as soon as the plaster has hardened sufficiently to be cut without displacement or crumbling. The material can then be cut quite easily with a strong sharp knife. The edges of the fenestrum and the adjacent surfaces of the splint can be readily made impermeable to any secretions that may come in contact with them by brushing them over with melted paraffine. When the size of the opening required for the necessary exposure of the wound is so great that a connecting isthmus of sufficient strength is not left, the splint may be made in different sections, and the two sections connected together by metal or wooden bars (Fig. 76).

Plaster-of-Paris may often be combined to excellent purpose with other materials, as wood, metal strips or wire, or wire gauze, in the construction of splints for special purposes. A typical example of this is seen in

Fig. 75.—Windowed Plaster-of-Paris Bandage (*Esmarch*).

Esmarch's plaster-of-Paris suspension splint for excision of the wrist, which is a combination of a wooden or wire splint (Fig. 77), a wire suspension bar (Fig. 78), and an interrupted plaster splint. The wooden splint is

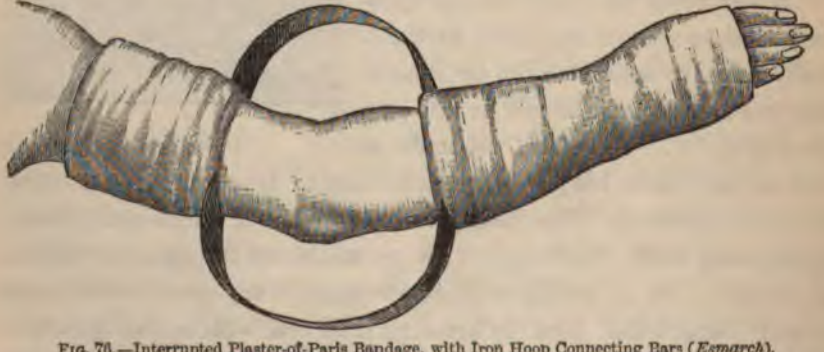


Fig. 76.—Interrupted Plaster-of-Paris Bandage, with Iron Hoop Connecting Bars (*Esmarch*).

very narrow at the wrist, bent to a right angle at the elbow, and provided with a hole for the internal condyle of the humerus. The arm is placed upon the splint, which is padded with cotton wool and bandaged with

plaster-of-Paris rollers. Finally, after the suspension bar has also been bandaged on with plaster-of-Paris rollers, the arm is suspended by a rope and pulleys, as in Fig. 79. One of the merits of plaster-of-Paris splints, as well as of plastic splints in general, is the readiness with which they are suspended, and thus facilitate the movements of the patient without endangering disturbance of the wound to the degree that is unavoidable

Fig. 77.—Wooden Portion of Esmarch's Suspension Splint for Excision of the Wrist.

when the wounded member lies on an immovable surface. The limb, after having been encased in the splint, should be swung by pieces of rubber tubing or bands, passed around it at suitable distances from each other and tied to a bar above (Fig. 80).

The removal of a plaster bandage may be accomplished best by using a suitable saw for dividing it. A large-sized Hey's saw makes a very con-

Fig. 78.—Wire Suspension Bar.

venient instrument to be used for this purpose. The saw devised by Hunter, of Philadelphia (Fig. 81), is an excellent model. It is necessary that the teeth should be widely set, so that a wide groove may be cut in the bandage for the free passage of the saw. A powerful pair of shears, with one blade flattened so as to be insinuated beneath the splint, will suffice to slit up many splints. Fig. 82 shows the original model of Seutin, which has not since been improved upon.

Subsequent Dressings.—Too early and too frequent interference with a wound may become an obstacle to the highest degree of success in securing its undisturbed healing. Infrequent dressing is eminently conducive to that absolute rest which is to be kept in view in whatever method of

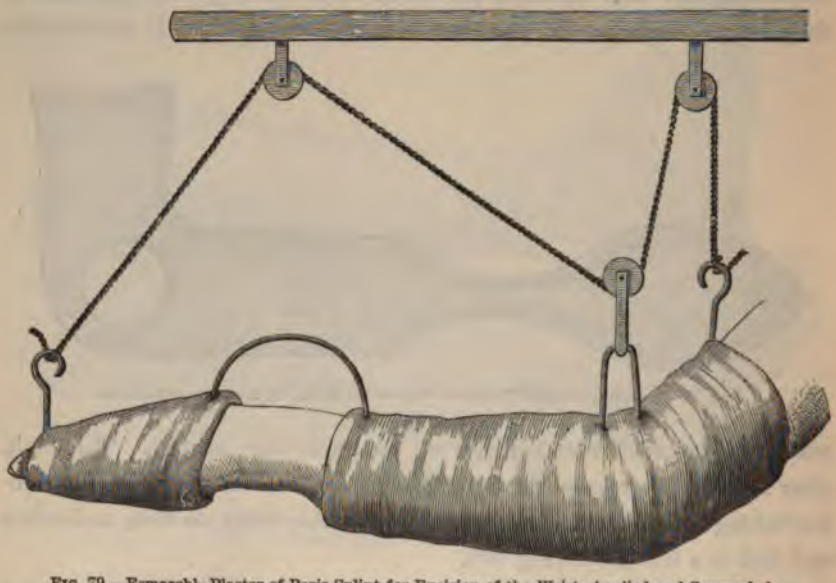


Fig. 79.—Esmarch's Plaster-of-Paris Splint for Excision of the Wrist, Applied and Suspended.

treatment is adopted. When the first dressing of the wound has been conducted in accordance with the principles of rational wound-treatment which have been described; when the bleeding has been carefully and per-

Fig. 80.—Fenestrated Plaster-of-Paris Splints Suspended (*J. D. Bryant*).

manently arrested, the wound-surfaces and recesses perfectly cleansed and rendered aseptic, the retention of secretions and débris provided against by efficient means of drainage, the divided surfaces brought together as

far as possible and retained in apposition, and adequate means of protection against septic infection, mechanical injury, and motion, whether passive or active, has been provided, its rapid and undisturbed healing will certainly take place, with but few changes of dressings necessitated. The after-cares from the surgeon will be limited to a watchful oversight of the means of protection and immobilization, of drainage and apposition, that have been employed, that they be removed, substituted, or reinforced by others as soon as they are no longer called for, or have become inefficient. The course of the wound in its repair is largely dependent upon the per-

Fig. 81.—Hunter's Plaster-Bandage Saw.

fection which each one of the great indications for treatment which have been dwelt upon may have been met at the first. It has been seen that the most frequent cause of wound-disturbance, as well as the cause of the most perilous of the disturbances that may complicate wounds, is the conjunction of the agents and the subjects of decomposition. The prevention of access of the one, and the removal, as fast as formed, of the other, therefore constitute the two great commandments of the law of wound-repair, each of which, equally, every one who undertakes to treat a wound must comply with to the best of his ability, if he would acquit himself of re-

Fig. 82.—Seutin's Plaster Shears.

proach for the results of disturbance that may supervene in the progress of the wound. Inflammatory, erysipelatous, gangrenous, or septicæmic complications attacking wounds can no longer be regarded as unfortunate and unavoidable accidents, but must be regarded as the results of errors or failures in the treatment which the wounds have received. It is especially in the treatment of fresh wounds that the responsibility of the surgeon is the greatest, since "the fate of the wounded man depends almost entirely upon the application of the first dressing." When a neglected wound, or

one already manifestly septic, comes under the care of the surgeon, his responsibility is less than in the case of fresh wounds, but his duty still is manifestly to persistently endeavor to convert the dangerous septic wound into one that is aseptic, even if the trial be made in vain.

When the first dressing of a wound has been successfully and perfectly accomplished, it may not need to be disturbed for some days; in some cases, as has been mentioned in connection with special methods of protective dressing, ten and fourteen days may be permitted to pass without removing the dressings, by which time the wound may be found to be quite or nearly healed. In all cases where the external protective dressings remain dry, as long as the wound remains free from pain and fetor, and there is no acceleration of the pulse nor elevation of the temperature, the dressings may remain undisturbed. The use of the thermometer as a guide to the surgeon is an invaluable aid, a rise of temperature being a sign that should invite immediate examination of the wound for the beginnings of possible disturbances there, although it may also be occasioned by intercurrent troubles in other parts or organs of the body.

It is impossible to fix arbitrarily the periods for the renewal of the dressings. Each case must be a law to itself, according as the special conditions which it may present may determine. The indications which the drainage, the sutures, the compresses, the protective appliances may present have been sufficiently set forth, as to the principles that govern their use, in the various sections already devoted to their consideration.

In the changing of the dressings, and indeed in all the manipulations required about the wound, the utmost gentleness should be used, coupled with a deliberate speed that is possible only when nothing is done without a purpose, and every preparation for accomplishing that purpose has been made beforehand. When splints are applied for purposes of immobilization, they should be so applied that they shall not interfere with the removal of the immediate dressings of the wound when necessary, in order that no necessity may arise for the premature removal of the splints.

ANODYNES.

The various preparations of opium, by the relief of pain, and the feeling of general well-being and comfort that they create, by their tendency to quiet muscular spasm, and to steady the heart's action, may contribute in an important degree toward securing the desired rest for a wound.

They should be given in small and often-repeated doses, according as pain, restlessness, irritable pulse, or muscular twitching may demand for their control. When an anæsthetic has been given, as in surgical operations, the administration of an opiate by suppository introduced into the rectum, or hypodermically, should be made while the patient is yet under the influence of the anæsthetic.

CHAPTER XII.

THE RELIEF OF DISTURBANCES OF HEALING—INFLAMMATION—GANGRENE—ERYSIPELAS—SEPTICÆMIA.

Treatment of Inflammation—Opening the Wound—Incisions—Removal of Foreign Bodies—Position—Compression—Reduction of Heat—Cold Compresses—Evaporating Lotions—Irrigation—Immersion—Ice-bags—Cold Water Coils—*Relaxation of Vessels—Abstraction of Blood—Interrupting the Blood-supply—Résumé—Treatment of Gangrene*—Incisions—Continuous Antiseptic Irrigation—Stimulants—*Treatment of Erysipelas*—Antiseptics—Subcutaneous Injections of Carbolic Acid—Superficial Applications—Naphthalin—Tonics and Stimulants—Antiphlogistics—*Treatment of Septicæmia*—Local Disinfection—General Treatment.

INFLAMMATION.

The treatment of an inflamed wound must be directed both to the removal of the cause of the inflammation and to the relief or mitigation of the conditions that attend it, or result from it. The substitution of destructive inflammation for the constructive processes that make for the repair of a wound never takes place, except as the consequence of defects either of wound-cleanliness, or of wound-protection, or, more frequently, of both, hence the first duty of the surgeon, when in the presence of an inflamed wound, is to seek for its causes and to address himself first to their removal.

With but few exceptions an inflamed wound is a septic wound, and the cause of the inflammation is the irritation of the products of decomposition of retained secretions. It is, accordingly, those wounds in which the retention of secretions is most difficult to prevent, as in wounds of joints and other cavities, wounds leading down to fractured bones, and deep, irregular-punctured wounds, that severe inflammation is most frequently met with.

To give free vent, therefore, to all wound-secretions that may have been retained is the first thing to be attended to in the treatment of such a wound. This may require nothing more than the cutting of a stitch, so

that the natural gaping of the wound may suffice for the required vent, or it may require counter-incisions and the use of drains.

Whatever means the special conditions of the parts may make necessary should be thoroughly and systematically employed until ample provision for the entire flowing away of the secretions as fast as formed has been secured. "In all spreading and diffuse inflammations, incision is the remedy of paramount utility, because death of subcutaneous tissue occurs early—sometimes, indeed, as the initial lesion of the case—and, until an avenue of escape is provided for the sloughs, pus formation tends to advance progressively beneath the skin, where it is liable to be attended by indefinite destruction of tissue. When timely and sufficiently ample openings have been provided, the destructive process is in most instances arrested at once. Incisions save the integument, which would otherwise be destroyed by the spontaneous formation of gangrenous patches—a result which, without this remedy, is almost inevitable. In this way, indeed, both the necessity and the great value of early, free, and bold incision is demonstrated."[1]

Mechanical irritation, motion, and premature use of a wounded part may provoke inflammation by preventing or breaking down adhesions, inflicting mechanical violence upon tender tissues, interfering with repair, and thus presenting anew the conditions in which septic changes may become rife. The search for and removal of foreign substances that may have been left in a wound, as splinters of wood, pieces of glass, rusty nails, bits of clothing, detached pieces of bone, etc., must not be overlooked in cases where their possible presence may be the cause of the inflammation.

When the causes of the inflammation have been removed, all those means by which perfect rest of the part can be secured become of the greatest importance. The part must be placed in an elevated and comfortable position, and must be immobilized. Then may be used such other means to relieve or mitigate the pain, heat, and swelling of the part, and to overcome the vascular congestion upon which they depend, as the conditions of the wound and the judgment of the surgeon may indicate as needful and practicable. The means available for this purpose act either by compressing the swollen tissues, reducing the heat, relaxing the vessels, abstracting blood, or interrupting the blood-supply.

Compression.—The practice of compression with immobilization is at-

[1] Van Buren: International Encyclopædia of Surgery, i., p. 151.

tended with the most marked advantage in the treatment of inflamed wounds. All that has been said with reference to their use as protective measures to healing wounds applies with yet more force to an inflamed wound. The compression must be even and continuous, and must be so applied as to avoid any constriction. Pain and strangulation, with gangrene, may result from attempts at circular compression in which every part from its distal extremity upward is not equally compressed. Properly applied compression is attended with comfort, and whenever it produces discomfort the means of compression should be rearranged or removed altogether. An elastic roller bandage of pure rubber (Martin's bandage) can be used to make compression with very great advantage, and may be adapted to every region of the body. Rollers of soft cotton cloth, or of flannel, with layers of cotton wool, enveloping the inflamed part, may be used for making pressure. Compressed sponge, confined by a bandage, and then supplied with water, may be made the agent of strong and elastic pressure by its tendency to swell. Bags of water, or of other substances that will permit an even adaptation of their surface to that of the inflamed part, may be laid upon inflamed parts so as to exert uniform compression.

The Reduction of Heat.—The judicious use of cold, locally applied, is of especial value in antagonizing the tendency to the excessive active hyperæmia which marks the earlier phases of inflammatory action. It abstracts heat, constringes the vessels, and acts as a local sedative. Its power to diminish vascular excitement may be pushed to such an extreme that deficient nutrition of the parts to which it is applied may be produced, and deficient repair, even local death, result. Its use should be confined, therefore, to the control of acute inflammatory conditions, or as an application to wounded parts in which inflammation is both prone to occur and to be followed by disastrous consequences, as in wounds of joints and of the head. Cold should be so applied as to maintain a continuously uniform low temperature, for when applied intermittently each application is followed by more or less vascular reaction which disturbs the repair of the wound.

Cold Compresses.—Cold may be applied by enveloping the part in compresses wrung out in cold water, the compresses being frequently changed before they have become warmed. This is apt to disturb the injured part, and is likely to be neglected, so that it is an unreliable and objectionable method, though the one most frequently adopted.

Evaporating Lotions.—Compresses may also be wetted with a dilute alcoholic lotion, the rapid evaporation of the spirit sufficing to cool the parts. Lotions containing a mixture of equal parts of ammonium chloride (sal ammoniac) and potassium nitrate (saltpetre) lower in a marked degree the temperature of parts to which they are applied. A strength of half an ounce of each salt to the quart of water is the proportion most frequently used.

Irrigation.—Continuous cold may be applied to a part by arranging a vessel of cool water above it so that a constant dripping of the water upon it may be secured (Figs. 83 and 84). The part should first be covered by

FIG. 83.—Irrigation (*Esmarch*).

a piece of cloth large enough to extend upon the integument several inches beyond the wound, upon which the water from the irrigator shall fall and then be diffused. The evaporation of the water from the compress is quite rapid, and increases greatly the cooling effect of the irrigation, so that it is not necessary to employ water of a very low temperature. The water as it runs away should be caught upon an inclined plane (Fig. 83), or upon

some waterproof material beneath the limb (Fig. 84) and guided into a receptacle below. The needful apparatus for irrigation may be extemporized from very simple materials. A common wooden or tin pail, a bottle with the bottom knocked out, an empty fruit-can, a wash-basin, a cup, anything that will hold water, and any material that will absorb or convey water suffices. The water may be conveyed by making a siphon of a bit of rubber tubing (Fig. 83), or glass tubing (Fig. 84) or out of a piece of

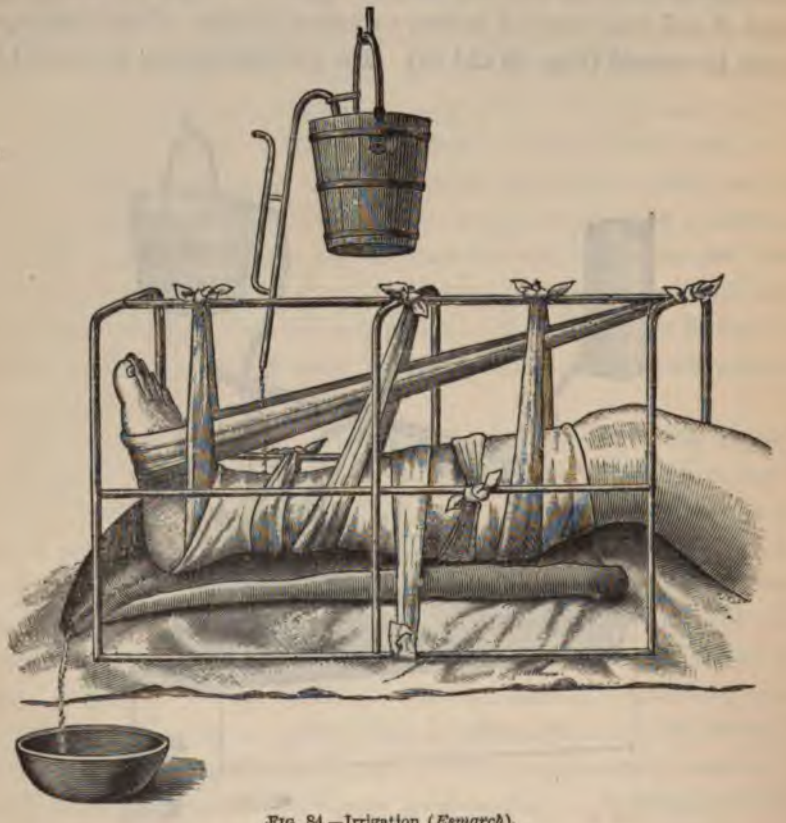


FIG. 84.—Irrigation (*Esmarch*).

candle-wicking or similar absorbent fabric. Tubes may be inserted into the bottom of the vessel containing the water, and the amount of the flow regulated by the use of suitable plugs in these outlet tubes.

Immersion.—Wounds of the extremities may be immersed in cold water, suitable vessels being provided in which the inflamed member may be laid. A very low temperature is not needed for producing energetic reduction of temperature. The frequent addition of cool water to keep

the temperature of the bath down to the desired point will require watchful care.

Ice-bags.—Rubber bags (Fig. 85), or, when they are not accessible, bladders, may be partly filled with pounded ice and be laid upon a part. This method is particularly convenient for the application of cold to the head and to the joints. If the direct application of the ice-bag is too cold,

FIG. 85.—Ice-bag (*Esmarch*).

This book is the property of
COOPER MEDICAL COLLEGE,
SAN FRANCISCO, CAL.
and is not to be removed from the
Library Room by any person or
under any pretext whatever.

layers of cloth may be laid between the ice-bag and the part. An ice-bag may be securely closed by wrapping its closed mouth about a wooden disc or large cork, as in Fig. 85, and tying it by a tape.

Cold Water Coils.—Cold may be continuously applied to any part of the surface of the body by placing upon them mats formed of rubber tubing coiled to the requisite size and shape, the coils being secured by wire tape, and by passing, either by fountain or siphon action, a continuous current of cold water through the tubing from a reservoir placed at a convenient height.[1] Similar mats may be made of soft metal (Leiter's tubes). The extremities may be encircled by spiral turns of tubing

[1] W. M. Chamberlain: The Uses of Rubber Tubing in the Therapeutics of Reduction of Body Temperature. The Medical Record, April 29, 1882, p. 469.

through which the water may flow. Fig. 86, from Esmarch's "Handbook," shows a forearm thus encircled by a tube, one end of which is placed in a

FIG. 86.—Cooling Coil (*Esmarch*).

vessel filled with ice-water, while the other, hanging down, discharges the current into an empty pail. Fig. 87 illustrates the application of the cold

FIG. 87.—Cooling Coil (*Otis*).

water coil to the penis.[1] The coils of tubing are retained in place by a band of cotton or linen cloth.

THE RELAXATION OF VESSELS.—Warmth and moisture produce a soothing

[1] F. N. Otis: The Cold Water Coil in Inflammation of the External Male Genital Apparatus. The Medical Record, January 9, 1875, p. 19.

and relaxing effect upon an inflamed part directly opposite to that of cold. They promote dilatation of the vessels and thus relieve tension by enlarging the calibre of the vessels through which the blood is crowding. They favor exudation and thus relieve the congested vessels. They relieve pain and thus diminish the effect of reflex irritation. Moist heat may be applied by compresses wrung out in hot water—fomentations—by poultices and by immersion in hot water. The compresses and the poultices should be covered over by a layer of impermeable material, as oiled silk or rubber tissue, to retain the heat and moisture and lessen the frequency with which the application requires renewal. For poultices any substance capable of being reduced to a soft mushy consistence with hot water may be employed, but on account of the general facility of its management and the length of time that it retains its heat and moisture, ground flaxseed is to be preferred. Poultices should not be made so thick as to be burdensome by their weight, nor should they remain unchanged for a longer period than six hours. Immersion in hot water is the most beneficial method of procuring vascular relaxation, and is to be chosen whenever practicable. It may contribute likewise to drainage and to wound cleanliness.

The Abstraction of Blood.—Local bleeding may have a very beneficial effect upon an inflammation by the relief of tension which it produces upon the congested tissues and the over-distended vessels. It may be obtained by scarifications, by incisions, by scarifications and cups, and by leeches. The bleeding which may attend the incisions required for the more free drainage, and for the relief of tension in inflamed parts is of value in immediately relieving the congestion caused by previous conditions.

The Interruption of the Blood-supply.—The attempt to diminish the amount of blood supplied to an inflamed part is a logical result of the recognition of the fact that the active afflux and undue retention of blood in the part is the most prominent factor in the distress and damage which an inflamed part suffers. Against this active hyperæmia most of the remedial measures which have been used have been directed. Position, compression, cold, and blood-letting have been seen to be of benefit either by preventing the blood from going into a part, or by removing it from it. This may be yet more effectually accomplished by cutting off the main stream of blood from the engorged tissues, by which device the veins are left of their original calibre to drain away the superabundant blood, while the volume and force of the arterial current are greatly diminished. As the result, the over-distended capillaries soon recover their normal calibre, and

the ordinary processes of nutrition and repair are re-established. Interruption of the blood-supply may be accomplished by the various means which have been discussed in connection with the arrest of hæmorrhage (Chapter VI.), viz.: forced flexion, compression of the main artery by means of the finger, tourniquet or a weight, acupressure, and ligation.

Forced flexion is particularly applicable to the treatment of inflamed wounds of the forearm and hand, and is easily and well combined with the means of elevation, compression, and immobilization. The interruption of the current through the main trunks of the lower extremity is better accomplished by the ligature. As has been pointed out by Mr. Maunder,[1] if compression is used to temporarily interrupt the current, and for any reason should be relinquished too soon, the blood would then not only pass to the inflamed spot through the enlarged smaller vessels, but also through the main channel, and thus an additional and injurious supply would result. The gravity of the proposed operation of ligation will cause this means of controlling inflammation to be resorted to only in cases of destructive and excessive inflammation. For the first definite formulation of the indications for the use of ligation of the main artery of supply, as a means of arresting acute traumatic inflammation, and for its practical demonstration by a series of cases, the profession is indebted to Dr. H. F. Campbell, of Georgia, under whose direction, in 1862, in the military hospitals of Richmond, Va., ligation of the femoral artery in four cases, and of the brachial in three cases, was performed for the arrest of violent and uncontrollable inflammation. In all these cases the pain, the swelling, and turgescence were almost immediately relieved, and the most remarkable improvement was soon seen in the character of the discharges.[2] Six of these cases were reported by him in his chapter on the ligation of arteries, in the "Manual of Military Surgery," published by the Surgeon-General of the Confederate States Army in 1863, in which the author (pp. 104, 105) states that in all these cases the Hunterian operation was chosen with the distinct end in view of combating and checking, if possible, the destructive progress, and, in some, the septic tendency of the inflammation. Dr. D. F. Wright, of Tennessee, reported in 1866[3] five other cases, under

[1] Surgery of the Arteries, London, 1875, p. 163.

[2] Henry F. Campbell: The Hunterian Ligation of Arteries to Relieve and Prevent Destructive Inflammation. Southern Journal of the Medical Sciences, August, 1866.

[3] Therapeutic Effects of the Ligation of Arteries. Richmond Medical Journal, April, 1866.

his observation, in which the Hunterian ligation of the main arterial trunk of a limb had been done for the arrest of secondary hæmorrhage, and in all of which, immediately from the date of ligation, "large tumefaction had been superseded by recovery of the original contour, fetid ichorous discharge by laudable suppuration, and phagedenic gangrene by vigorous granulations."

Mr. Maunder, of London, in his work on "The Surgery of the Arteries," reports six cases of ligature of arteries for the control of traumatic inflammation, and after discussing the various aspects of the practice, summarizes his experience, thus:

"That ligature of the superficial femoral artery has arrested acute inflammation consequent on wound of the knee-joint.

"That ligature of a main artery will quickly diminish profuse suppuration and prevent death by exhaustion.

"That, while it arrests profuse suppuration, it will, by allowing the patient to gain strength, afford an opportunity for amputation at a future time.

"That gangrene and secondary hæmorrhage, as the result of ligature, should not be anticipated in the healthy subject."

Résumé.—The various resources which have been mentioned for antagonizing and mitigating traumatic inflammation are sanctioned by the practice of the past and by the authority of surgical teachers; but the more accurate knowledge of the present with reference to the essential causes of inflammatory disturbances of wounds must relegate them to a less important place, while the greatest importance must attach to those measures which may rid a wound of the agents and subjects of sepsis. Free incisions for the relief of tension and the escape of débris, adequate drainage, cleanliness in the aseptic sense of the term, with proper protection and perfect rest, afford the surest and speediest means of overcoming inflammation, since they remove its causes, carry away its products, and favor in the highest degree the natural nutritive processes of the part, by means of which recovery from damage already sustained is to be secured, and repair of the original injury is to be accomplished.

GANGRENE.

The appearance of spreading gangrene in a wound calls for immediate energetic antiseptic treatment to destroy the micro-organisms, the caustic products of whose vital activity, as they successively invade new tissues,

produces the gangrenous phenomena. All necrosed tissue should be removed at once with knife and scissors, and the living tissues exposed should be freely and thoroughly cauterized by the eight per cent. chloride of zinc solution, which should be injected into every recess and irregularity of the wound. The swollen and infiltrated tissues leading from the gangrenous focus, particularly the intermuscular interstices and the subcutaneous connective tissue, should be opened by numerous small incisions through the integument to permit the escape of secretions and of débris and to enable the disinfecting fluid to be introduced into as many places as possible. Longer incisions and counter-incisions may be made as shall be required for the relief of tension and for the freest imaginable drainage. When gangrene has attacked a wound, the wound must be kept exposed, so that its condition may be under continuous observation while the means of powerful and permanent disinfection are being employed. An open method of treatment with continuous antiseptic irrigation offers a most effective means which will overcome the most serious cases of sepsis when all other precautions have been found insufficient. The adjacent integument should be frequently anointed with vaseline to protect it from the macerating influence of the irrigation.

As an irrigating fluid, a dilute solution of carbolic acid (one per cent.) is adequate. As a substitute for carbolic acid in making permanent irrigation, Bruns,[1] of Tübingen, advocates the use of weak solutions of acetate of alumina (one-half of one per cent.). This has sufficient antiseptic strength, and does not produce eczema or intoxication. The antiseptic irrigation should be continued until the wound is rendered perfectly aseptic. Iodoform dressings then will be particularly applicable as protective and absorbent dressings.

The general strength of the patient must be kept up by the liberal use of alcoholic stimulants, by nutritious food, by tonics, and by anodynes.

ERYSIPELAS.

When the repair of a wound becomes disturbed by erysipelas, the patient should at once be isolated. A surgeon or attendant should not pass from the care of an erysipelatous case to that of a healthy wound until after the most thorough antiseptic precautions for securing cleanliness

---

[1] *Die permanente Irrigation mit essigsaurer Thonerde. Berlin. klinische Wochenschrift*, 1878, No. 30.

have been observed. The appearance of erysipelas is always due to some defect or neglect in the antiseptic precautions. Greater care is required to prevent the occurrence of erysipelas than of suppurative and putrefactive reactions in general, but adequate means to keep wounds aseptic have been proven to be efficient barriers against its development. The remarkable experience of Nussbaum that, although previous to the introduction of aseptic methods of treating wounds into the General Hospital of Munich, almost every wound was attacked with erysipelas, and after its introduction no instance of erysipelas occurred, has already been referred to in a previous chapter (Chapter III.). Similar, though less absolutely perfect results, have attended the attempts at aseptic methods of other surgeons. The first thing to be recognized, therefore, upon the appearance of erysipelas in a wound is that it is of specific septic origin, and that it most especially calls for those methods of treatment which are adapted to septic wounds. It is no longer correct to say that the pathology of erysipelas is still involved in obscurity; the researches of Fehleisen, referred to in Chapter III., page 44, have definitely demonstrated, what had already been inferred by many observers, that erysipelas is due to the infection of a wound by a specific micro-organism, a micrococcus. Based upon this, it is possible to construct a rational and efficient therapeutics of the disease.

Treatment may be directed for the purpose of either:

1. Destroying or rendering inert the specific micrococcus. *Antiseptics.*

2. Increasing the resisting powers of the invaded tissues. *Tonics and stimulants.*

3. Alleviating the local inflammation and removing its products. *Antiphlogistics.*

Antiseptics.—The power of antiseptic substances is more readily exercised as a preventive means than as a curative resource. The infiltration of the tissues with the micro-organisms tends to render them inaccessible to antiseptic applications, unless these be of sufficient strength to destroy the tissues as well. The germs, according to Fehleisen, spread along the lymphatics only, but their dissemination takes place not only along the course of the lymph stream, but in all directions, without reference to the direction of the lymph current. Their destruction, when isolated, by antiseptic agents, was experimentally demonstrated by Fehleisen with carbolic acid and corrosive sublimate. The isolated micrococci, exposed to the action of a three per cent. solution of carbolic acid for twenty seconds, remained active and potent; when exposed for thirty seconds, their devel-

opment was imperfect and retarded ; when exposed for forty-five seconds, they were destroyed altogether. A one per cent. solution of corrosive sublimate destroyed them much more quickly, an exposure of ten to fifteen seconds being sufficient to prevent their development. Fischer,[1] of Strassburg, claims for naphthalin that it has a specific power to antagonize the micro-organisms of erysipelas.

Subcutaneous Injections.—Hueter,[2] of Greifswald, in 1875 recommended the early subcutaneous injections of dilute watery solutions of carbolic acid. Hypodermic injections of salicylic acid have also been used with success.

The use of subcutaneous injections of antiseptic solutions to abort attacks of erysipelas has been found to be most certainly successful when employed at the onset of an attack ; later, when the infiltration of the pathogenic organisms and the inflammatory reaction has attained a greater extent, it becomes less probable that the antidote can be injected so as to come in contact with the noxious particles in sufficient quantity and to the necessary extent. Differences in the stage of the disease at which these injections are practised, and in the manner in which the injection is performed, will explain much of the differences in the results obtained by different surgeons.

The antiseptic to be used must be one that is not too irritating, that is diffusible, and that will not coagulate the tissues among which it is introduced. Carbolic acid, in dilute watery solution, answers these indications better than any other agent of equal antiseptic power. Carbolic acid was the antiseptic used by Hueter. The method of its use finally settled upon by him [3] was to inject three to five hypodermic syringefuls of a three per cent. watery solution of the acid, at numerous points, into the healthy subcutaneous tissues along the borders of the erysipelatous patch. These injections demand repetition once or twice, according to the intensity of the inflammation and its tendency to extend. Even three or four repetitions may be needed before the erysipelas will cease to advance. In but few cases will this method of treatment fail to greatly circumscribe the disease.

E. Boeckel,[4] of Strassburg, after testing the method in a series of cases,

---

[1] *Centralblatt für Chirurgie*, Nov. 29, 1882. *Beilage*, p. 3, Congress of German Surgeons, 1882.

[2] *Deutsche Zeitschrift für Chirurgie*, 1875, 4 Bd., Heft 5 and 6.

[3] Schüller. *Jahresbericht. Deutsche Zeitschrift für Chirurgie*, 1878.

[4] *Gazette Médicale de Strasbourg*, 1875, No. 5.

concludes that, while injections of carbolic acid are not a panacea, yet they constitute the most certain remedy which we possess. By injecting, morning and evening, from five to six hypodermic syringefuls of a one and a half per cent. carbolic solution, one-fifth of an inch from the inflamed border, along the entire circumference of the erysipelatous patch, he was frequently successful in arresting a very severe erysipelas within twenty-four hours.

Tillmans,[1] of Leipzig, is of opinion that subcutaneous injections of carbolic acid have their greatest usefulness in preventing or mitigating a threatened outbreak of erysipelas, and that for this end they should be energetically used at the beginning of an attack. He quotes Küster, of Berlin, as also of the opinion that, at the onset of an attack, the measure is of great value, but that later it is wholly or nearly worthless.

To some surgeons it has happened that abscesses have frequently formed at the sites of the injections. This, however, can be easily avoided by care that only a clean syringe be used in making the injections, and by directing the point of the needle in various directions, so that the fluid injected is diffused over a larger extent of tissue.

Superficial Applications.—The application of antiseptic substances to the surface of the skin in many cases is of benefit, but the results are comparatively uncertain and weak. Tincture of iodine, tincture of the chloride of iron, tar, strong solutions of nitrate of silver, of sulphate of iron, of salicylate of sodium, of carbolic acid, and other agents, have been used by various surgeons, and in turn have been esteemed as of value and as inefficient.

Naphthalin, made into an ointment with vaseline, or other appropriate excipient, in the strength of from ten to twenty per cent., and thoroughly smeared over the affected surfaces, will cause the unpleasant subjective symptoms of erysipelas to disappear rapidly, followed by a more slow subsidence of the swelling or œdema. Usually its application beyond the limits of the disease will check its further spread, or at least mitigate it.

Tonics and Stimulants.—The general depression and febrile reaction which attend attacks of erysipelas are themselves the results of septic infection by absorption of the products of the local disease. With the subsidence of the local disease, the general symptoms also disappear, and yet by reason of the general depression of the natural resisting power of the

---

[1] Erysipelas. *Deutsche Chirurgie, Lieferung* 5, 1880.

body which they produce, they may contribute to the greater severity and the prolongation of the local trouble. Those general remedies, therefore, will be of value which shall either contribute to general nutrition, or shall act as stimulants and roborants. A supporting diet is of importance. The use of proper means to keep the digestive and excretive apparatus in active condition must be resorted to. Tincture of the chloride of iron, quinine, and opium are of great value in many cases.

Antiphlogistics.—Since the local inflammatory phenomena which mark erysipelas constitute its most obvious symptoms, the mitigation of these phenomena constitute a very important part of the treatment called for. The treatment of the inflammation is to be conducted on the same principles and by the same methods which have been discussed in the first part of this chapter. When the inflammation is limited to the skin only, those applications which will soothe and protect it find use. A layer of absorbent material kept saturated with a lotion of lead and opium (liquor. plumbi subacetatis, ℥ j. ; tinct. opii, ℥ ss. ; aquæ fervent., Oj.) is an excellent application ; or the skin may be dusted with finely powdered starch, lycopodium, or subcarbonate of bismuth, and covered by a layer of cotton wool ; or it may be anointed with oil or vaseline, either pure, or containing some antiseptic, or sedative, or astringent substance.

When the deeper structures are involved in the inflammation—phlegmonous erysipelas—all the resources of art for the control and relief of inflammation become drawn upon. Position, rest, cold, heat, immersion, antiseptic irrigation, multiple incisions, drainage, compression, depletion, are to be used, each in accordance with the indications and methods already laid down for combating inflammation in general.

SEPTICÆMIA.

Septicæmia is a generic term that includes every grade of general septic infection produced by the absorption of septic wound-products, from a slight febrile reaction to the cases of more intense blood-deterioration with the formation of diffused secondary suppurating and septic foci (Pyæmia).

Local Treatment.—All that has been said as to the treatment of local septic disturbances applies with equal force to the treatment of general blood-infection, for where further new supplies from local septic foci are arrested, the return of the blood to its normal state, by the elimination and destruction of the septic matters already mingled with the circulating

fluids, begins at once to be manifest. Local disinfection, therefore, is the first and most important matter to be accomplished in the treatment of traumatic septicæmia.

Secondary abscesses, whenever they are accessible, should be treated upon the same principles as the primary suppurating dépôts.

Resection of joints and amputation of limbs may become necessary in some cases when less radical means fail to render the wound aseptic.

General Treatment.—The indications to be met by general treatment are to mitigate general symptoms, to favor elimination, to counteract prostration, and to relieve organic complications as they arise.

PART II.

SPECIAL WOUNDS.

SECTION I.

VARIETIES THAT MAY OCCUR IN ANY PART OF THE BODY.

CHAPTER XIII.

SUBCUTANEOUS WOUNDS—INCISED WOUNDS—CONTUSED WOUNDS—LACERATED WOUNDS.

Subcutaneous Hæmorrhage—Restriction and Absorption of Effusions—Massage—Dry Cupping—Sorbefacients—Inflammation—*Incised Wounds*—Rest—*Contused and Lacerated Wounds*—Peculiarities—Secondary Hæmorrhage—Primary Cleansing—Drainage—Necrosis of Tissue—Coaptation—Period of Granulation—*Contused Punctured Wounds*—Incisions.

SUBCUTANEOUS WOUNDS.

The perfection of the protection which the unbroken skin affords to a subcutaneous wound simplifies very much the treatment which is demanded, while it at the same time diminishes very greatly the dangers to be apprehended of disturbances arising in the course of its healing. As subcutaneous wounds may be of every grade of severity, from a slight bruise to ruptures and lacerations of important organs, and the disorganization of extensive masses of tissue, the amount and character of the treatment which they must receive will greatly differ. Mere inspection may not be sufficient to reveal the amount of damage, the repair of which is to engage the assistance of the surgeon, nor may its full amount be recognizable until after some time, when its subsequent course shall have demonstrated more fully its extent by the degree of functional disturbance which results from it.

The most important indications of treatment presented by subcutaneous wounds are the control of hæmorrhage, the restriction and absorption of effusions, and the maintenance of the injured parts at rest until their continuity has been restored with tissue of sufficient firmness to again endure the functional activity of the part.

Subcutaneous Hæmorrhage.—The mutual pressure of the parts among which the bleeding point lies is usually sufficient to restrict within moderate limits subcutaneous hæmorrhage. This is still further aided by the

irregularities of the rents in the vessels themselves, which tend to entangle the fibrine of the blood, and to produce clot-plugs that may seal them up. Hæmorrhages into the great cavities of the body, however, having less restraint upon their flow, tend in many cases to speedy death. When large arteries are ruptured subcutaneously, it is necessary to freely expose the point of rupture by incision, and ligate upon both the proximal and the distal sides of the rupture. The further treatment of the wound is then removed from the category of subcutaneous wounds. The most frequent subcutaneous hæmorrhages are those which attend contusions and result from rupture of subcutaneous veins and capillaries, the amount of the extravasation depending upon the vascularity of the part and the severity of the contusion. The connective and muscular tissue interspaces become infiltrated with the effused blood, and even more or less distinctly bounded cavities containing blood may be formed. The discolorations produced from the wide diffusion of extravasated blood, by their extent, mark its degree, and persist for a long time.

Special treatment to control hæmorrhage of this character is rarely called for. When the continuance of hæmorrhage is evident, compression by means of an evenly applied bandage, with or without an intervening compress, will suffice for its control. The application of cold would also be an additional available resource.

Restriction and Absorption of Effusions.—The arrest of hæmorrhage is to be followed by the use of means to restrict the amount of active hyperæmia within the limits needed for repair. Cold lotions, evaporating lotions, or ice-bags, are of value as applications to overcome any tendency to excessive afflux, but the most valuable and powerful resource exists in immobilization and methodical compression after the methods described in Chapter XI. When material division of structure, as in the case of fractures of bones, or the rupture of muscles or tendons, has taken place, this immobilization, in a position that shall favor the apposition of the divided surfaces, must be continued until complete and firm reunion has been established.

The absorption of effusions is likewise promoted in a remarkable degree by compression. To this should be added, especially in the more severe cases of contusion and sprain, those means of preventing or overcoming the passive dilatation of the blood-vessels prone to remain after the first period of active hyperæmia, and of diffusing the effusion, and thus promoting its absorption, which are found in methodically rubbing, kneading,

percussing, and rolling the soft parts, with passive movements, which constitute "massage."

Massage may be used very early after an injury, within the first twenty-four hours. The skin over the affected part should be anointed with oil to protect it, for it is the deeper tissues that are particularly to be affected by the kneading. The thumbs and fingers are then to be applied with steady and firm pressure, their force being graduated according to the tenderness of the part, so as through the skin to rub, and knead, and roll the deeper tissues, diffusing the exudations present, stimulating the languid circulation, and exciting the absorbents. The manipulations should be begun beyond the margins of the tumefied and painful spots, which should be gradually approached. The soothing effect of the rubbing, when patiently and delicately applied, is such that soon pressure and movement over the points of chief injury are readily tolerated. By massage a more speedy relief from pain and swelling, and an earlier restoration of the function of the part can be secured in many cases than by any other method. It is particularly of value in the treatment of contusions, distortions and sprains of joints, and their sequelæ.[1]

Dry Cupping.—The application of dry cups to the surface of the skin over the area of injury will powerfully assist in diffusing the effusions consequent upon contusions of the deeper parts, and will contribute to the comfort and the more speedy restoration of the function of the injured part.

Sorbefacients.—The use of various lotions for their presumed power in stimulating the absorption of effusions, though a popular and common resort, cannot, as a rule, be commended as of value. Their power to allay the violence of the primary afflux by their cooling or sedative properties is more marked. According to Gross,[2] the most trustworthy sorbefacient is a strong solution of chloride of ammonium with the addition of a small quantity of vinegar, applied upon folded flannel, covered with oiled silk, and renewed six or eight times in the twenty-four hours.

Douching a part with hot water, as hot as can be borne without suffering, continued for from twenty to thirty minutes, acts energetically in producing contraction of the dilated vessels and in restoring tone to the circulation and nutrition of an injured part, and in promoting absorption

[1] Douglas Graham, M.D.: The Treatment of Sprains by Massage. The Medical Record, August 11, 1877, p. 504.

[2] System of Surgery, 1882, vol. i., p. 354.

of effusions. As an immediate application after a contusion or sprain, hot water, either in the form of a douche, bath, or by compresses, is preferable to cold applications by reason of the diminished tendency to passive congestion which follows its use. When the effused blood is collected in depôts, if its presence is a cause of discomfort or serious functional disturbance, it may be removed by aspiration, or through incision made in the overlying integument, provided strict surgical cleanliness be used to prevent the agents of putrefaction from gaining access to the exposed cavity.

Inflammation, complicating subcutaneous wounds, is to be treated in accordance with the general principles laid down elsewhere. When suppurative and putrefactive disturbances intervene, free incisions to evacuate septic matters must be made, and the general treatment already insisted upon for septic wounds followed.

INCISED WOUNDS.

The treatment of simple cut or incised wounds presents fewer elements of difficulty than do those forms of wounds which are accompanied by more extended damage to the adjacent tissues. In the arrest of hæmorrhage, which in general will be accomplished with but little difficulty, the means of hæmostasis should be adopted which will not be likely to introduce sources of disturbance in the after-course of the healing. Bleeding from all but vessels of considerable size will be arrested by exposure to the air, or by the application of hot water, aided by compression. The mutual compression of the wound-surfaces against each other, after they have been brought into apposition, serves to restrain any tendency to farther hæmorrhage. When ligatures are required, only those that are aseptic should be employed, the preference being given to those of animal material that can be spontaneously absorbed.

The hæmorrhage from incised wounds in which large blood-vessels are opened seldom ceases spontaneously; they constitute the most dangerous class of wounds, and quickly terminate fatally from loss of blood. The most energetic and instant resort to measures for the arrest of hæmorrhage is called for in these cases. When a vessel is but partially divided, it is more difficult to stay the bleeding from it than if the division is complete. In such cases the first thing to be done is to complete the division of the vessel.

The cleansing of the wound is less difficult to accomplish; its surfaces are lined with a minimum amount of devitalized tissue, for the absorption and removal of which, without disturbance arising from its decomposition, the ordinary reparative energy of the adjacent tissues is usually quite adequate when coaptation is effected, even without minute precautions to exclude from contact with it, while exposed, any pathogenic germs. The drainage of incised wounds, when proper care is exercised to maintain their deeper parts in apposition, is very simple. In the more extensive wounds, it needs the use of capillary drains for the first twenty-four hours only, during the period of the most energetic afflux consequent upon the wound; in a large proportion of cases, where compression and immobilization of the wounded part can be effected, no provision for drainage is required.

The apposition of the wound-surfaces should be attended to with the utmost care and minuteness, so that by the use of sutures, compresses, bandages, and position, the coaptation of every part should be perfect, and no spaces be left for the collection of secretions. The reunion of parts which have been almost entirely separated from the body may not infrequently be secured by minute attention to their coaptation. Albanese, of Palermo, Italy, reported[1] at the session of the International Medical Congress at London in 1881, a remarkable instance of such reunion. In this case the wrist had been almost completely cut through, with the bones and the flexor and extensor tendons, so that the hand hung, held to the forearm only by a slip of skin in the dorsal region about one and a half inch wide. The radial and ulnar arteries were ligated, the severed surfaces were brought into contact with pin sutures, and immobilization was effected by a plastic splint. Slight gangrene appeared in the thenar region. The temperature and sensibility of the hand and fingers were sensibly lowered for a long time. The vitality of the hand as a whole was preserved, and its reunion to the forearm accomplished with ankylosis at the carpal articulation, and mobility at the radio-carpal articulation. The fingers were at first immovable, but gradually acquired some movement, until finally they became quite useful.

The protective dressings required by incised wounds, the coaptation of whose surfaces is possible, are very simple. Exposure of the line of suture to the air, so that the desiccation of the slight amount of secretion that

[1] Transactions International Medical Congress, 1881, ii., p. 438.

gathers there may form a protective crust gives excellent results when the conditions of the wound are such as to make it practicable. A light, dry, clean absorbent dressing of some kind is all that is required at any time.

The provisions of "rest," in the case of incised wounds, may and should be made absolute. When proper care has been taken in the other details of the treatment of an incised wound, that infraction of its rest involved in the removal and readjustment of its dressings may be long deferred; the surgeon can consider his dressing as having been perfect only when, after the expiration of a week or ten days, during which no local discomfort or constitutional disturbance having been noticeable, removal of the dressings and inspection of wound shows it to be healed throughout.

The development of inflammatory disturbance or of septic conditions, in the course of the repair of an incised wound, unless the inflammation and septicity were already present before it came under the care of the surgeon, is a reflection upon the character of the treatment, and calls for special explanation upon the part of the surgeon to exonerate himself from blame therefor.

CONTUSED AND LACERATED WOUNDS.

Since the extent of the tissue damage which has been sustained by the parts that are the subjects of contused or lacerated wounds is not to be determined by the amount of the apparent injury visible at the first examination, its treatment has to be conducted with a degree of care and watchfulness, and provision for probable causes of disturbance, that do not embarrass the surgeon in the management of incised wounds. The surface breach is generally much less than the breach sustained by the deeper tissues, and the wound is complicated by the presence of much tissue that has been damaged by the traumatism, the life of which is to be preserved only by great care in fostering its nutrition, and preventing the access of inflammatory disturbances.

The primary hæmorrhage from these wounds is less apt to imperatively demand the attention of the surgeon for its control than in the case of incised wounds, on account of the favorable condition of the parts for its spontaneous arrest produced by the nature of the traumatism, even large vessels being frequently spontaneously plugged by the retraction and inturning of their separated inner tunic, and by the interlacing of the irregular ends of the external tunic and the surrounding connective tissue.

On the other hand, secondary hæmorrhages occur with more frequency on account of the sloughing of parts of the wall of a vessel, either because its vitality had been so far destroyed by the original force, which had yet fallen short of opening it, that it failed to become restored, and so ultimately necrosed, or because the vessel became involved in destructive inflammatory processes complicating the after-course of the wound.

The period during which the separation of sloughs caused by the original injury is taking place, is thus a period of danger. This is usually between the sixth and twelfth days after the infliction of the wound. During this time, accordingly, special watchfulness against the occurrence of hæmorrhage is to be exercised.

The period of reaction from shock is also particularly liable to be complicated by hæmorrhage in the case of contused and lacerated wounds, since, though the blood-current, while weak from the depressed action of the heart, often finds the natural obstructions left behind by the laceration of the tissues sufficient to arrest it, yet when it is again driven with more energy by a restored heart, its force may be sufficient to sweep away these comparatively weak obstructions, and to determine copious hæmorrhage.

The period of reaction is therefore to be watched with especial care to guard against possible hæmorrhage ; and in the first dressing of a wound involving vessels which may possibly bleed, it is the part of wisdom to apply preventive ligatures to them, though they may not be bleeding at the time, providing this does not involve undue disturbance of the wound in other respects. Aseptic ligatures should be used, and care should be taken to apply the ligature to a sound portion of the vessel.

Nevertheless, should a surgeon think it best to defer interference, as long as no bleeding takes place, it will be found that in many cases no interference will be necessary; but such a course will exact increased watchfulness until the repair of the wound has sufficiently far advanced to demonstrate the permanency of the spontaneous hæmostasis. When, however, secondary hæmorrhage has once occurred, then the application of a ligature is imperative, even though the bleeding may have again spontaneously ceased as the heart's action has weakened, for so soon as the reaction again comes on, and the heart beats strongly once more, the hæmorrhage will surely recur.

The primary cleansing of the wound should be conducted with great care, the more since the recesses and irregularities, which its surfaces are likely to present, favor the lodgement of irritating matters, and because in

many instances foreign matter is ground into the exposed surfaces at the moment of the injury. All detached particles of bone and soft tissue should be carefully removed, and tissues into which foreign matter has been so ground that the complete removal of this dirt is impossible should be trimmed with scissors or knife. Bruised portions of tissue that are still attached should be carefully cleansed and replaced, and preserved from further traumatism, since much that appears to be hopelessly destroyed may yet be saved in many cases by care in fostering its nutrition.

Thorough irrigation of a contused and lacerated wound with an antiseptic lotion, until no element of sepsis be left within it, is imperative, for all the conditions of such wounds are such as to create and present to a large degree the material favorable for the rank development of septic organisms. The natural resisting power of the tissues, which enables the surfaces exposed in ordinary incised wounds to resist the development of sepsis, and to preserve the minute devitalized fragments of tissue that are present from undergoing putrefaction, is no longer to be relied upon in the class of wounds under consideration ; in these the bruised wound-surfaces have to struggle to retain their own vitality, and larger masses of devitalized tissue, and more copious effusions of putrefiable secretions have to be disposed of.

The consecutive cleansing of the wound, to admit of the free escape of wound débris of every kind during the period of repair, will require the fullest provision for drainage from all its recesses. All the methods of securing this, which have been discussed in the earlier part of this work (Chapter VIII.), may find their application in the treatment of these wounds, and must be applied according to the judgment of the surgeon, so as to secure the immediate and full removal from the cavity of the wound of all putrefiable material as fast as formed.

Efforts at accomplishing apposition of the wound-surfaces must be subordinated to the needs of drainage and the provision for the unhindered separation of necrotic tissue. In cases of severe contusion a degree of uncertainty will always exist as to the ability to regain vitality which the injured tissues may exhibit, and a certain amount of necrosis is to be expected and provided for. This necrosis will be reduced to a minimum in proportion as the provisions for making and keeping the wound aseptic are thorough and successful. When adequate antiseptic measures are practicable, greater efforts at securing coaptation of the wound-surfaces should be made, since they will be more likely to be rewarded with a cer-

tain degree of primary union than when antiseptic precautions are neglected. Special care should be observed to avoid all tension of the wounded tissues in endeavoring to approximate them. With this precaution, and those required for drainage, coaptation may be attempted by any of the means which are at the disposition of the surgeon for that purpose.

In a large proportion of contused and lacerated wounds there will be such an amount of destruction of tissue that any attempt at closing it to secure primary union will be manifestly contra-indicated. In such cases the efforts of the surgeon are chiefly directed toward protecting the wound from sources of disturbance during the time that the separation of the devitalized tissue and the repair of the breach by granulation is being effected.

These are the cases in which local septic inflammations, gangrene, erysipelas, and general septic infection are most prone to occur. For the prevention of these accidents the precautions of "antisepsis" and of "rest" should be rigorously observed.

Contused Punctured Wounds, such as those formed by the thrusting into the tissues of a splinter of wood, a nail, a bayonet, or any other substance which is capable of making a deep and narrow wound-track, are likely to present difficulties in treatment by reason of the trouble that they may give in securing their disinfection and drainage. The first thing to be attended to, after the removal of the puncturing substance and the stanching of hæmorrhage, if there be any, is the disinfection and cleansing of those parts of the wound that are accessible, and then placing the part at rest. If there has been no septic material introduced into the deeper parts of the wound at the time the puncture was made, and adequate protection be afforded it thereafter, speedy repair without disturbance may be looked for. When, however, from any cause, inflammation of the deeper portions of the wound develops, in proportion as it is deep and narrow will the inflammatory effusions be pent up, and their putrefaction, with attendant local irritation and general septic infection, be likely to occur. They are septic wounds and require the immediate and energetic application of the means of treatment described as required by such wounds (Chapter VIII., page 157).

The value of free and early incisions for the relief of pent-up effusions cannot be overestimated in such cases. The following strong putting of the value and necessity of this measure in such cases is by Bryant, of London.[1]

[1] On Wounds. International Encyclopædia of Surgery, ii., 40.

"In the treatment of all punctured wounds, the surgeon has only to remember that, as their danger consists in the difficulty of providing efficient drainage, so their treatment turns upon this deficiency being remedied; and the surgeon who, on the first appearance of local or general symptoms indicative of the presence of retained fluids, makes an outlet by one or other of the means which have been suggested—even when the outlet is only for the escape of pent-up serum—will be more successful than another who, from timidity or other cause, leaves the case to run its course, till a large inflammatory abscess has formed from the irritation caused by the fluids which should have been evacuated. In all punctured wounds, which do not heal quickly by primary union, and in which secondary inflammation occurs, with its necessary effusion, it is the surgeon's duty to find an outlet for the fluids of the part as soon as the fact of their retention is clear. The artificial formation of a free vent for these fluids will be followed by relief, both locally and generally, and will almost always save tissue; whilst delay in adopting this practice is not only locally deleterious, but may even prove dangerous to life. When thecæ of tendons, fascial and fibrous coverings, as of bones, are involved, the necessity of adopting this practice is more important, if possible, than when the softer tissues are implicated; and an incision into the deep parts for the evacuation of even simple serum, by relieving tension, will often prevent the extension of the inflammation, and prevent destruction of tissue."

CHAPTER XIV.

GUNSHOT WOUNDS.

Peculiarities of Gunshot Wounds — Hæmorrhage — Wound-cleanliness — Immediate Antiseptic Occlusion—No Immediate Exploration—Classification—Statistics of Reyher—Non-occlusive Treatment—Enlargement, Cleansing, and Disinfection—Probes and Probing—Removal of Bullets—Immobilization.

Gunshot wounds are contused and punctured wounds, but have a special character by reason of the length to which their track may attain, the extensive concealed injuries they are likely to present, the difficulties, both near and remote, which the frequent lodgement of the missile among the tissues is prone to create, and the circumstances in which, upon the battle-field, most of such injuries are sustained.

The principles of treatment which are applicable to contused and punctured wounds in general find their most important application in the treatment of gunshot wounds, and by their scrupulous observance the repair of these wounds will be greatly facilitated and the occurrence of the wound-disturbances, which are prone to manifest themselves as the sequelæ of gunshot wounds, will be avoided.

Hæmorrhage.—Special interference for the arrest of hæmorrhage is only likely to be demanded in the case of wounds of vessels of considerable size; in such cases the rule is imperative to enlarge the wound, expose the bleeding vessel and ligate it upon both the proximal and distal side of its wound. Should the vessel not have been already completely severed by the ball, it should be divided between the ligatures after their application.

When the wound-track is in the vicinity of a large vessel, the possibility of secondary hæmorrhage should be borne in mind, and special watch be kept upon the case till its repair has sufficiently advanced to make such danger no longer to be apprehended.

Wound-cleanliness.—The cleansing of the wound involves the measures necessary for its exploration, the removal of the missile and other foreign matter that may have been carried in with it, and the destruction of sepsis.

The relative importance of these measures appears from the fact that the disastrous results of gunshot wounds, which are not quickly fatal from the vital importance of the parts damaged, are always consequent upon inflammatory, suppurative, and infective disturbances which complicate their repair. These disturbances have their origin in septic contamination of the wound-track, and gain their aggravated proportions from the natural obstacles which the wound-track presents to the escape of the septic matters afforded by the contaminated wound-secretions and débris.

The prevention of the septic contamination of the wound-tract, therefore, is to be considered as of the greatest importance to be observed in all the manipulations to which it may be subjected, and is to be kept in view from the first moment that the wound is received. The presence of the missile, or other foreign substances carried in with it, or splinters of bone, are less to be feared than the subsequent admission of septic elements. As MacCormac ("Antiseptic Surgery," p. 268) has remarked, "Gunshot wounds, in general, present many features of what are called subcutaneous wounds. There is a small external opening which bears no proportion to the extent of the damage within, and it has been long observed that some gunshot fractures, and wounds of joints even, may heal just as simple fractures do, and the inference is that they healed because of the closure of the external wound, and the absence of suppuration depended on the non-admission of septic elements, at all events in sufficient quantity to excite decomposition."

Immediate antiseptic occlusion, that is, the application to the external wound, or wounds, of tampons of absorbent antiseptic material, as early as possible after the infliction of the wound, should be done; for no period of time, no matter how small, can be safely allowed to elapse between the reception of the injury and its protection from septic invasion. Absorbent cotton impregnated with iodoform, salicylic acid, or boracic acid may be selected for such immediate occlusive purposes. The antiseptic balls recommended by Esmarch to be supplied as a part of the outfit of a soldier are made of salicylic wool and jute, contained in salicylic gauze, and enclosed in a square of oiled paper. The tampon to be invariably applied directly to the wound, and the oiled paper used as an external covering. The whole secured with a bandage.

Jute impregnated with chloride of zinc has been recommended for such tampon as more powerfully and certainly antiseptic in its action. It may be applied in the same way.

When no antiseptic protective substance is immediately attainable as a covering to the wound, it should be left exposed to the air without any covering whatever, inasmuch as the air is less likely to be septic than any ordinary dressing which would otherwise be applied. By such exposure, also, desiccation of the secretions about the wound aperture would be found, and a protective crust thus be formed.

When the necessity of interference with the wound for the arrest of hæmorrhage is present, its urgency may compel the disregard of every other precaution; but, with that exception, it should be considered an absolute rule that nothing should be brought into contact with it for any purpose which has not been previously rendered aseptic, and that all interference of any kind is to be abstained from until it is possible to surround it with the necessary provisions against sepsis.

When no septic matter has been carried in with the bullet, and no septic matter has been introduced by the surgeon in explorations or efforts at removal of the missile, and early sealing of the external wound has been accomplished, either by the scab formed by the desiccation of its discharges, or by occlusion with an antiseptic tampon, the wound is reduced to a subcutaneous injury, and the greater part of the difficulties in its treatment become eliminated.

The chief obstacle to the general adoption of the practice of primarily sealing up the external aperture of a gunshot wound lies in the undue importance which has been attached to the early removal of the missile, when embedded, as if the foreign body in itself was the exciting cause of the disturbances of repair that mark the usual course of the healing of such wounds.

On the contrary, as Esmarch expresses it, "the damage done by the bullet is caused by it in its course; the harm that is added comes mostly from the examiner's finger."

Reyher,[1] in detailing the remarkable results obtained, under his direction, in the Russo-Turkish war, remarks: "I have never explored for the purpose of extracting bullets; never even, for this sole purpose, after patients had reached the hospital. In the hospital I have only removed them when their removal seemed imperative on account of inflammation or suppuration in their immediate vicinity. In a large number of cases, then, the parts have healed around the bullet, in spite of the generally

[1] *Die Antiseptiche Wundbehandlung in der Kriegschirurgie.* Volkmann's *Samml. klin. Vorträge*, No. 142, August, 1878.

accepted ideas of practice to the contrary. It is not impossible that in some of these cases the foreign body may prove a source of future irritation, but its extraction subsequently in private practice will be much less dangerous than in the infected atmosphere of a military hospital, while its removal, then, will be from tissues which are no longer infiltrated, and from which all blood-extravasation has long been absorbed."

The mere lodgement of a bullet, therefore, in the tissues, is not of itself a sufficient indication for opening up the wound-track by an exploring finger or probe, and exposing the wound to the dangers of septic contamination which such a manœuvre would entail, nor, even if the exploration was done with adequate antiseptic precautions, would it be justifiable to disturb the wound by the new traumatism of the exploration, until distinct evidence had appeared that the missile was seriously disturbing the repair of the wound by its presence.

Immediate Exploration of a gunshot wound is called for only in cases in which the manifest nature of the wound is such, by reason of the extensive laceration and destruction of tissue present, that its occlusion is impracticable, and the questions of excision and amputation require to be decided.

Classification of Gunshot Wounds.—Gunshot wounds thus divide themselves, from the standpoint of treatment, into two classes: 1, Those which are capable of primary occlusion of the external wound, and of conversion into practically subcutaneous wounds; and, 2, those which must be treated as open wounds throughout.

By immediate provision for the protection of the wound from septic contamination from without, and by careful abstinence from any explorations of it, until the symptoms of inflammatory disturbance declare that interference is necessary, an aseptic course of the healing of the wound may be secured in a large proportion of cases. Reyher, in his observations before alluded to, has recorded the following valuable statistics of the comparative safety and value of such attempts to occlude gunshot wounds.

Out of twenty-eight cases of gunshot wound of the knee with bullet embedded in the part, the four which were treated in accordance with these principles, *from the outset*, recovered with movable joints; eight, in which antiseptic precautions were not adopted until the next day, died, as well as four which had no such treatment at all; while of the remaining twelve, which had no *primary* antiseptic treatment, and required either intermediate or secondary amputation, eleven died. Of forty-six cases of wounds of different joints treated as above, six died—mortality 13 per cent.; of

these, nineteen required primary resection, of which only two died—10.5 per cent. Of seventy-eight cases similar in other respects, but in which antisepsis was a secondary consideration, or from which bullets had been extracted, forty-eight died—61.5 per cent. Of another series of sixty-two shot wounds of joints without primary precautions, thirty-nine died—63 per cent. So in cases of shot fractures of long bones, of sixty-five treated from the first, only five died—7.6 per cent. Of twenty-nine not so treated, eight died—27 per cent. In a neighboring hospital to his own, during the campaign in the Caucasus, Reyher saw seven cases of uncomplicated wounds of soft parts die of pyæmia; under his own primary antiseptic measures he lost but one such. In another series of sixty-five fractures treated secondarily by antiseptic rules, twenty-three died—35.3 per cent. As illustrating the reduced number of cases of pyæmia, altogether of eighty-one cases of miscellaneous wounds treated primarily, only five died from blood-poisoning—6.1 per cent.; whereas, of one hundred and forty-three not so treated, forty-six died—32.1 per cent. Of fifty-seven various wounds of skull, buttocks, and soft parts, all treated antiseptically from the start, *not one died.*

With all his cases, Reyher saw erysipelas but three times. There were, moreover, but two cases of tetanus, and none of gangrene. The number of lives saved by the adoption of this method by Reyher was, therefore, in proportion, from three to four times as many as were saved under the older methods. Out of the forty-six cases of gunshot wounds of joints it was only necessary in *four* cases to depart from the system of primary occlusion without interference; whereas, of seventy-five cases of similar wounds treated by secondary antisepsis, drainage, etc., in fifty-four of them resections or amputations were required.

The second class of cases, which must be treated as open wounds, include those in which the extent of the external wound is too great to give any hope of securing its primary occlusion, those in which these attempts have been made but have failed, and those in which such attempts have been deferred or omitted until the wound has become manifestly septic, by reason of its exposure, its having been subjected to uncleanly and premature explorations, or the application to it of contaminated dressing.

Even in this second class of cases, all explorations and other operative measures should be deferred until they can be done with the necessary precautions against septic contamination, or can be accompanied by adequate protective antiseptic dressing.

Treatment of Open Gunshot Wounds.—The treatment of this class of gunshot wounds should be conducted with scrupulous attention to the thorough disinfection of every accessible recess of the wound and to perfect freedom of drainage. The appearance of high fever, inflammatory swelling, progressive infiltration, gangrene, and other evidences of progressive septic contamination, call for the energetic and thorough application of all the resources for the destruction or control of sepsis which are within the command of the surgeon.

The primary examination and cleansing of the wound should be conducted with the view of making it aseptic. Frequent partial cleansing should be avoided ; repeated probings, cuttings, irrigations, and squeezings for the purpose of evacuating wound-secretions and débris, which keep up a continual irritation of the wound, should be replaced by a thorough primary examination and cleansing. This must be conducted with deliberation and minute attention to the ultimate object in view—the destruction and prevention of sepsis. An anæsthetic should be administered, and everything brought in contact with the wound should be carefully disinfected as used (see Chapters IV. and VIII.).

The external wound should be freely enlarged, when necessary, so as to permit the introduction of the cleansed and disinfected finger for purposes of exploration. For the purpose of enlarging the deeper part of the track, if the vicinity of important organs or the dangers of hæmorrhage make the use of the knife undesirable, it may be enlarged with blunt instruments, as dressing forceps introduced closed and then opened and withdrawn, thus acting as a dilator. The ordinary glove-stretcher suggests itself as a model for such a dilating forceps.

Bullets, splinters of bone entirely detached, pieces of clothing, and other foreign bodies, which are found during the examination, should be carefully extracted.

A bullet not infrequently, after having in the early part of its course inflicted injuries which require to be treated by the open method, continues its course in such a manner that the second part of its track may heal primarily behind it, and the bullet remain shut off from the first part of the wound, and then, becoming encysted, permanently remain without inducing further mischief.

The treatment of such a deep wound-track should be conducted on the same principles as those which control the treatment of the more superficial wound. It should not be probed, nor irrigated, nor in any manner in-

terfered with, until evidences of inflammatory disturbance of its walls appear. No search should be made along it for the bullet, much less should the mere presence of the bullet at its bottom be considered an indication for an attempt at its removal. The disinfection and drainage of the superficial portion of the wound should be conducted with all care and thoroughness. Should disturbances of the deeper portions of the wound manifest themselves, the exploration, cleansing, and drainage of that portion of the wound would then be required. Enlargement of the aperture of communication with the superficial wound, and free counter-incisions to the extent required for its easy and perfect drainage, and for the removal of any foreign and irritating bodies along its track will be necessary.

Probes.—For the exploration of wounds, the depth or course of which is such as to make them inaccessible to the finger, probes must be used.

For probing, a blunt-pointed, flexible rod should be used; the probing extremity should be sufficiently large, so that it should not easily make a passage for itself among the tissues; the shaft should be flexible, so that it may be adapted to the particular course of the track that is being explored, and should be long enough to admit of being easily and definitely controlled by the hand of the surgeon.

Rods of copper, silver, or pewter, a foot in length, with bulbous extremities of the diameter of an ordinary goose-quill, offer themselves as suitable material for probes. In an emergency the ingenuity of the surgeon will not fail to find some material from which a probe may be extemporized, although adherence to the rules which should guide the treatment of wounds, as given above, will remove explorations altogether from the list of operations of emergency.

Probing a wound should be done with all possible gentleness and care. The probe should be carefully cleansed and disinfected at the time of being used. It cannot be too strongly impressed on the mind of the surgeon, however, that all probing of a wound should be abstained from until such time as the final thorough examination and dressing of the wound can be performed, when, once for all, the use of the probe may be required in accordance with the restricted indications for its use which have been mentioned.

The Removal of Bullets.—When relegated to its proper place as a minor part of the general provisions for obtaining wound-cleanliness, the search for and the removal of the bullet calls for less consideration as to the methods by which it may be accomplished, and the apparatus needed for

its technique, than when it was esteemed in itself an indication of first importance to be met. Forceps with slender and firm jaws, with slightly projecting teeth that may increase the security of the grasp of the forceps upon the bullet, will facilitate the removal of a bullet when exposed. A blind groping for a bullet at the bottom of a deep sinus should not be attempted ; the enlargement of the external aperture, and the dilatation of the deeper track, as required for the purposes of cleansing and drainage of a wound, or the counter-incisions made when the length and location of the track demand it, should be ample enough to permit the sufficient exposure, and ready seizure of the bullet, if it is to be removed at all.

When the ball is suspected of having become impacted in a bone, or to have penetrated a joint, it is not to be interfered with, nor is an exploration for the purpose of determining the fact to be made, unless the wound, for other reasons, demands treatment as an open wound, or the efforts to secure primary occlusion have failed. If, upon exposure, it is loosely held, it may be readily removed ; if firmly impacted, it may be loosened by means of an elevator or chisel, and then removed.

Immobilization of parts which are the subjects of gunshot wounds is of extreme importance. Means of immobilization should be adopted as a part of the first dressing, it should be made continuous and absolute, and will prove a powerful accessory to the local antiseptic dressings in securing permanent primary occlusion of a wound.

Aside from penetrating wounds of the cavities of the body, and injuries of the large vessels, the great majority of those gunshot wounds which are likely to be complicated by dangerous wound-disturbances are those which involve bones and joints. The further consideration of the special methods of averting or controlling the dangers incident to such wounds belongs naturally to the discussion of that class of wounds in general.

CHAPTER XV.

EXTERNAL WOUNDS COMMUNICATING WITH FRACTURES OF BONES AND WITH JOINT CAVITIES.

Peculiarities—Value of Antiseptic Methods of Treatment—MacCormac—Classification—*Recent Injuries with Slight External Wound*—Primary Antiseptic Occlusion—*Recent Injuries with External Wound of Considerable Extent*—Primary Exploration and Cleansing—Counter-incisions—Splinters of Bone—Drainage—Suture—*Wounds of Joints*—Incisions—Partial Resections—Protective Dressings—Immobilization—After-treatment—*Injuries not Recent and Septic*—Favorable Cases—Cases with Pronounced Septic Infection—Disinfection—Immobilization—Fenestrated and Interrupted Plastic Splints—Honeycomb Plaster Splint.

The conditions presented by those lacerated and contused wounds, which are complicated by fractures of bones communicating with the wound, are such as are very favorable to the development of septic disturbances in their most aggravated form. Phlegmonous inflammation, prolonged suppuration, more or less sloughing of the contused and lacerated tissues, and necrosis of bone, are the ordinary attendants of the healing of such wounds when adequate precautions against sepsis are not observed in their treatment; while in this class of injuries, more than in any other, have the more formidable septic complications of erysipelas, gangrene, septicæmia, and pyæmia been rife.

The special feature possessed by these wounds which tends to aggravate the difficulties attending the treatment of severe lacerated and contused wounds in general, is the irritation of the wound by the movements of the bone fragments within it. The law of rest is thereby continually being violated, and a favorable condition for the development of septic disturbances maintained.

The treatment of these cases should be conducted from the first in such a way as to prevent, if possible, septic contamination, or to destroy or control it, when efforts at primary prevention have not been made, or have failed.

"In no kind of surgical injury," to borrow the language of MacCormac ("Antiseptic Surgery," p. 180), "have the results accomplished by the antiseptic method been more thoroughly satisfactory and complete than in compound fracture. In future we may expect to save the limb of the patient in all cases in which the extent of damage to the soft parts, vessels, and nerves is not such as to absolutely forbid the attempt. Even in cases where the expectation of saving the limb is not great, we are justified in giving the patient the benefit of the doubt, as we do not endanger his life by so doing; and should gangrene or any necessity for operation occur, we may then amputate without increased risk.

"Pyæmia and septicæmia, which have hitherto caused half the deaths among the fatal cases, should no longer occur; but only death from unavoidable causes, such as fat-embolism, delirium tremens, tetanus, senile bronchitis—causes not directly dependent upon the wound nor its treatment."

The difficulties which will attend the treatment of these cases will depend on the extent and character of the traumatism which has been inflicted, and upon the time at which they came under the care of the surgeon.

For purposes of convenient consideration they may be classified into three groups: 1. Cases in which the injury is recent, and in which the external wound is a slight puncture only of the skin. 2. Cases in which the injury is recent, and in which the external wound is of considerable extent. 3. Cases which are not recent, and which have already become septic. For each of these groups of cases a different mode of procedure offers the best results; for the first, primary occlusion, as in gunshot wounds; for the second, thorough primary disinfection of the whole extent of the wound, removal of blood-clots and loose splinters of bone, drainage, and finally occlusion by a closely fitting and evenly compressing antiseptic protective dressing; for the last, abandonment of occlusive dressings, and the substitution of open methods of treatment, with antiseptic irrigation.

Each of these groups requires consideration more in detail.

RECENT INJURIES WITH SLIGHT EXTERNAL WOUND.

When but a short time—an hour or two—has elapsed since the reception of the injury; when the wound through the integument is small; when there is no subcutaneous cavity filled with coagula, and the adjacent

tissues are not swollen and infiltrated, there is every reason to expect that by cleansing the external wound and the adjacent skin, by occluding the wound with an absorbent antiseptic dressing, and by keeping the parts at perfect rest, undisturbed and speedy healing of the external wound would be secured and the deeper injuries be reduced to the condition of subcutaneous injuries. All explorations of such an injury should be carefully refrained from.

The comminution of the bone, and the presence of splintered fragments at the bottom of the wound is not in itself sufficient to constitute an exception to this practice. Examples of such comminution of bone, with small external wound, are confined almost entirely to cases of gunshot injuries. Bruns,[1] in connection with this subject, remarks that even when splinters have become entirely detached and robbed of their periosteum, they will grow together again, provided suppuration is prevented and primary union of the external wound is secured. A splinter, even if the source of mechanical irritation, is not to be regarded as in itself an element inducing inflammation. The aspect of the case would, however, be changed if the foreign body, which had produced the splintering, had brought with it septic germs so as to infect the wound. The rule laid down for the treatment of gunshot wounds in general, that, where the injury is not such as to manifestly require primary amputation, the wound should be treated from the beginning by antiseptic occlusion and perfect rest, without exploration and enlarging, applies equally to wounds complicated by fracture of bone, however extensive the comminution may be.

The treatment required should be begun by a careful cleansing and disinfection of the skin over a large area surrounding the wound. Carbolic acid or corrosive sublimate lotions may be used for this purpose. The external wound should be irrigated with the same lotion, and should then be covered with thick layers of antiseptic, absorbent, and protective material (Chapter X.). Iodoform absorbent gauze, or cotton wool, presents the greatest advantages for this dressing; but many other substances, as the carbolic, naphthalin, and corrosive sublimate dressings will likewise be efficient. The dressing will be completed by a bandage of fixation and compression, and the application of an immobilizing apparatus.

As long as no symptoms, general or local, of wound disturbance manifest themselves, the dressing should be left undisturbed. When sufficient

[1] *Die allgemeine Lehre von den Knochenbruchen. Deutsche Chirurgie, Lief.* 27, 1 *Hälfte*, p. 358.

time for complete healing of the wound has elapsed, the wound-dressings may be removed, and the further treatment of the case be as for a simple fracture.

Should inflammatory disturbance in any degree manifest itself, the attempt at primary occlusion must be abandoned, and the cleansing, disinfection, and after-treatment of the wound be conducted as in the more severe cases next to be discussed.

RECENT INJURIES, WITH EXTERNAL WOUND OF CONSIDERABLE EXTENT.

The painful and protracted character of the manipulations required in the first dressing of this class of cases make the administration of an anæsthetic indispensable. Every portion of the skin which will be included in the subsequent dressings must be thoroughly cleansed *de rigueur* (Chapter VIII.), with soap and water, brush and razor, and finally purified with a carbolic acid or corrosive sublimate lotion. The wound cavity is next to be disinfected. If the existing opening is not large enough to permit the full exploration of the wound by the finger, and by retraction of its margins to permit inspection of all parts of the wound-cavity, it must be enlarged by the knife. All coagula and foreign matter are removed, and the wound cavity is then thoroughly irrigated with an antiseptic solution. The following more detailed directions for accomplishing the complete disinfection of the wound are given by Bruns (loc. cit.), from whose work, also, the greater part of what follows in the present chapter has been appropriated.

If long sinuses and pockets are present, counter-incisions should be made, so as to open them at their farther end, and secure through drainage in them. If extensive detachments of the skin are detected, numerous small incisions are recommended for the insertion of small drains. If the wound-opening is unfavorably situated for its enlargement, so that satisfactory disinfection of the breach, caused by the fracture, is hindered, as is the case sometimes in gunshot fractures, a drain should be introduced at the original aperture, and a counter-incision made into the wound-track, where it is most superficial, through which the disinfection may be performed. If it is discovered, on digital examination, that beyond the fragments pockets have formed, the bone at the point of fracture must be bent and its fractured ends forced up through the wound sufficiently to permit such deep recess to be irrigated. Excision of badly lacerated and contused

portions of soft tissue may, in some cases, be done with the scissors, when it is probable that the healing of the wound will be accelerated thereby.

All splinters and fragments of bone which have become completely detached from the soft parts, or which are held only by a small strip of periosteum or muscular fibre, as a rule, should be removed, since these fragments obstruct healing whenever suppuration and sepsis infest the wound, an occurrence which cannot always be avoided. When drainage will be facilitated, fragments of bone may be removed, even when more extensively adherent to the soft tissues. In this case the periosteum should be carefully preserved by using a periosteal scraper to detach the bone. Portions of periosteum, thus saved, will be of great value as sources of callus. All fragments of bone adhering to wide strips of soft tissue should be replaced in their normal position; their union may be expected with certainty if the wound be kept aseptic during its healing.

Next follows the drainage and the suture. Multiple short drains should be introduced into the wound; those in the principal wound should reach down to the point of fracture in the bone, but should never penetrate between the fragments. All the drainage-tubes should be clipped to the surface of the skin, and fixed by a safety-pin transversely inserted. All the wounds of counter-incision, as well as the principal wound, should then be sutured close to the drainage-tubes, whenever healing by first intention appears possible.

The treatment now detailed is to be employed not only when the wound communicates with a fracture of the shaft of a bone, but also when a joint cavity is opened into by the wound.

If the joint is not opened by a direct penetrating wound, but only by a fissure through the articular extremities of the bones forming the joint—an occurrence which may be verified by the hæmorrhage into the joint—the joint cavity should be opened by a free incision at a suitable point, and should be emptied of all serum and coagula, disinfected and drained. In given cases, the procedure amounts to nothing more nor less than a partial and irregular resection of the joint, the features of which will suggest themselves in the special conditions which these wounds will present in which antiseptic conservative methods will hereafter be more frequently adopted. Total resection will be limited, henceforth, to very grave cases.

After this primary cleansing and disinfection of the wound has been thoroughly accomplished, a protective antiseptic dressing should be applied with great care, and made to extend widely in every direction beyond the

wound. Gauze, or other absorbent material, impregnated with carbolic acid, iodoform, corrosive sublimate, naphthalin, or other antiseptic substance (Chapter X.), should be applied, crumpled and in multiple layers, and confined with an accurately applied roller bandage, so as to act as a means both of protection and compression.

Difficulties will arise if the wound is in such proximity to the thorax that the dressings extend upon it, since the movements of respiration will loosen the dressing. Martin's pure rubber bandage will be of especial service in such cases, accomplishing both the exclusion of air and compression.

The part is finally immobilized by the application of a proper splint.

The after-treatment is very simple, provided thorough asepsis has been obtained. In favorable cases, where healing by first intention is secured, a single change of dressing, after six to eight days, for the removal of sutures and drainage-tubes, is all that is necessary. The second dressing remains to the time of complete healing. In ordinary cases, where the wound does not show a tendency to primary union, the dressing is changed in from two to four days, according to the discharge; later, when the secretions become of a thick creamy consistence, the intervals between the dressings will be longer. Each change of dressing should be executed with rapidity, and yet with the greatest care. Exquisite caution should be exercised in the examinations and irrigations of the wound. The manipulations should be restricted to simply cleaning the surrounding integument with a pledget of absorbent cotton moistened with an antiseptic lotion, being careful not to disturb its relations. The drains should be removed as soon as the secretions cease to flow through them. The dressings should be renewed till the wound is filled with granulations up to the level of the surrounding skin. It will then suffice to apply a more simple protective dressing, covered by a plastic splint, as in subcutaneous fractures, till consolidation has taken place.

INJURIES, NOT RECENT, AND SEPTIC.

As injuries which are "not recent" are to be comprehended those which come under treatment after the lapse of twenty-four hours. The task to establish an aseptic course in these cases is obviously much more difficult; each patient, however, will present its special conditions, so that we have here, also, to differentiate between favorable and unfavorable cases, each kind requiring different treatment.

The more favorable cases are those which do not show an extended wound-reaction, even though unmistakable signs of decomposition of the wound-secretions are present. According to past experience, an aseptic course may, even under these conditions, be obtained—*i.e.*, an undisturbed healing by granulation, though frequently with increased suppuration, and often with necrosis of the ends of the fractured bone. The method to be pursued in these cases is virtually the same as in recent wounds—namely, enlargement, exploration, and disinfection of the wound, with subsequent antiseptic, protective, and occlusive dressings.

Contrasted with these favorable cases are to be placed those in which the pronounced picture of local sepsis is presented, either in consequence of neglect of antiseptic treatment, or of the inefficiency of that which has been employed. In these cases will be observed positive signs of decomposition of the wound-secretions, real ichorous discharge, more or less inflammatory reaction in the surroundings of the wound, in some cases gangrene of the badly contused soft parts, and progressive infiltration of the connective tissue with pus and gas.

Energetic disinfection is again demanded in these cases, though undeniably attended with greater difficulty, and not in all cases possible to be absolutely attained. All septically infected tissues must be freely laid open by incisions, so as to give entrance to the disinfecting substance; all gangrenous tissues must be removed with knife and scissors. Long incisions and counter-incisions should be made to open up the torn and infiltrated interstices of the muscular tissue. Where there is extensive subcutaneous infiltration of blood, as well as in those cases in which there is already present phlegmonous infiltration, numerous small incisions should be made, in addition, through the integument, for the removal of blood, pus, and gases, and to enable the disinfecting fluid to be introduced in as many places as possible. These multiple scarifications will render important service in opening the spaces between the long incisions. They should all be subjected to thorough antiseptic irrigation, and be kept open by small drainage-tubes.

Neither occlusion nor compression of the wound can be adopted in such cases, while it is further important that the changes which may be going on in it be capable of being observed at any time. For these reasons an open treatment, with permanent antiseptic irrigation is required (Chapter XII.).

This treatment should be continued until the wound has been rendered

perfectly aseptic, when it may be replaced by occlusive and compressive antiseptic dressings.

IMMOBILIZATION OF THE INJURED PARTS.

Means of immobilization must be resorted to both for the protection of the injured soft parts, and for the retention of the bone-fragments in proper position until consolidation has been accomplished. The presence of an open wound introduces elements of greater difficulty into the problem of immobilization than when a simple fracture is being dealt with, for, either the fracture-dressing must be removed every time the wound is examined, and then renewed, or must be so constructed as to leave exposed the wound and its surroundings. The latter plan is to be preferred, but is attended by greater technical difficulties, which grow with the circumference of the wound, and may be insurmountable in very extensive or multiple wounds.

The difficulties attending the employment of permanent dressings is quite apparent when antiseptic dressings also are to be used, and the question may have to be decided which of the two factors, antisepsis or immobilization, is of the greater importance, and which shall be infringed upon in their combination.

Slight motion of the extremities of the fractured bone, during a change of dressing, is not followed by any reaction when the parts are kept aseptic. Antisepsis, therefore, is the first requirement to be observed, especially in the earlier period of the case, until the fracture and the wound in the soft parts are covered with granulations. Antisepsis should be maintained scrupulously, even if it becomes necessary to remove the fracture-dressing from the limb to change the antiseptic dressing.

Except in the more simple and favorable cases the use of a permanent plaster-of-Paris dressing, applied so as to encircle the limb, and fenestrated, is not compatible with the requirements of the antiseptic dressing of the wound during the earlier days of its course. After the first critical period has passed, however, and the wound has become covered with granulations, and the amount of its secretions have somewhat diminished, such a dressing will be applicable. In cases of fractures occurring in patients suffering from delirium tremens, this dressing is indispensable.

During the first period of the treatment of these injuries, only such a means of immobilization should be employed as will allow the wound to be enwrapped with an antiseptic dressing that will extend over a wide cir-

cumference about it. Not always the same kind of dressing will answer; the seat of the fracture, and the special conditions of each case should be our guide.

Plastic splints are to be recommended in most cases. Splints made of pasteboard, felt, or plaster-of-Paris are especially applicable, as they can be adapted to any part of the body. The width of the splint should extend over about one-third of the circumference of the limb. In general, the splint is applied over the antiseptic dressing, if possible, on that side of the limb where it will be least soiled by the wound-secretions. They should be secured by moist starched bandages, so that the turns, when dry, will firmly adhere to each other. For suspending the limb, holes may be punched in the splint, and cords for suspension drawn through them.

FIG. 88.—Bowed Plaster Splint for Compound Fracture of the Knee-joint (*Beely*).

Such splints can easily be removed at each change of the dressing. In some cases, however, in which the wound is not too large, and is favorably located, the splint might be enclosed within the antiseptic dressing, so that it might remain when the latter is changed. In such a case, the splint should be narrowed opposite the wound, and wrapped in impermeable tissue or lined with antiseptic cotton. It may then be placed directly upon that part of the limb opposite the wound, next to the skin. Over all, the antiseptic dressings are to be applied, and the whole secured as before recommended.

Another way to avoid removal of the splint, when the wound-dressing is changed, is to have a ∩-shaped arch formed on the splint, opposite the wound (Fig. 88), so as to render the wound and its surroundings accessible all around. Such a splint would need to be reinforced by a strip of hoop-

iron, bent in the same way, and inclosed in the plaster. Such a splint resembles much the interrupted circular splint (Figs. 76, 79).

Concave splints of wood, tin, or wire, applied over the wound-dressing, may be used to advantage in many cases.

Some kind of suspension-splint, with extension by means of adhesive plaster strips, a weight and pulley, affords, as a rule, the best advantages for carrying out the antiseptic treatment of a wound complicated with fracture.

The fenestrated or interrupted plaster-of-Paris encircling splint may be employed with advantage as soon as the process of healing has suffi-

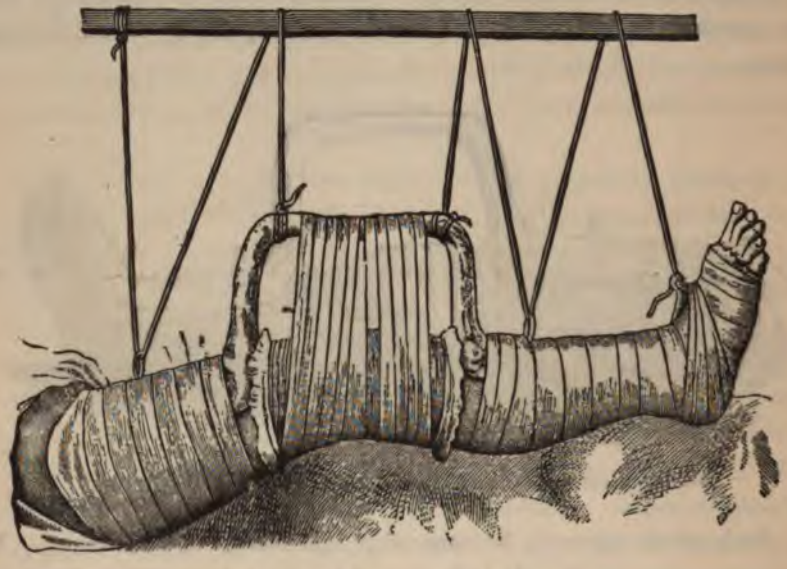


Fig. 89.—Bowed Plaster Splint, Applied and Suspended.

ciently advanced to exclude danger from sepsis and inflammation. This period may arrive within two or three weeks, if the conditions are favorable, but may be delayed for a much longer time. When the secretions have nearly ceased, the wound is covered with granulations, and the incisions have either healed or have become superficial granulating surfaces, the perfect immobilization of the fracture assumes greater importance than the rigid antiseptic treatment of the external wound. No method of fracture-dressing can secure the desired immobility of the bone-fragments, and yet permit the necessary attentions to the wound, but the encircling plaster splint, fenestrated or interrupted.

The application of the plaster-dressing in these cases requires great care and experience to preserve the continuation of the antiseptic treatment. If the wound is small, fenestration of the splint will suffice; if it is extensive, or if several wounds coexist, it must be interrupted.

Application of the Fenestrated Splint.—The fenestrated plaster-of-Paris splint is applied as follows: The wound and its immediate vicinity, to the extent of one to two inches, are covered temporarily with a number of folds of antiseptic gauze or cotton, which will afterward form a projection in the plaster casing, by which the location of the fenestrum will be marked. As a basis for the plaster dressing, the whole limb, after having been well cleansed with an antiseptic lotion, should be wrapped in antiseptic cotton. The plaster bandages should then be applied in the usual way (Chapter XI., p. 211). The plaster bandage may be reinforced by the insertion between its layers of one or more longitudinal strips of sheet-iron.

FIG. 90.—Lath-gypsum Splint of Pirogoff (*Esmarch*).

As soon as the plaster is sufficiently hard, the fenestrum is made, and the temporary antiseptic dressing is removed through the window. The spaces at the margins of the opening are filled thoroughly with antiseptic paste (ten per cent. carbolized oil and common chalk or whiting). Finally, the whole space within the fenestrum is filled with antiseptic protective material; over all a layer of impermeable tissue is placed which shall overlap the circumference of the fenestrum from two to three inches, being secured in place by a gauze bandage.

The limb should then be suspended.

If it becomes necessary for the fenestrum to be so large that the splint is materially weakened by it, a wooden strip might be placed longitudinally over the limb, crossing the window, as in the "Lath-gypsum" dressing of Pirogoff (Fig. 90). In this dressing of Pirogoff, after a strong plaster-of-

Paris splint of coarse sackcloth, soaked in plaster cream, has been applied to the calf, two large balls of tow, saturated with the plaster cream, are placed upon the anterior surface of the leg; a wooden lath is then fastened upon the tow with broad strips of linen, which are also impregnated with the plaster cream.

FIG. 91.—Interrupted Plaster Dressing (*Esmarch*).

The interrupted plaster dressing (Chapter XI., p. 212) is suitable in extensive injuries of the soft parts, or in multiple incisions and counter-incisions. The bridges (Fig. 91), preferably of sheet-iron, which connect the two pieces of the dressing should extend along the whole length of the sections of the dressing into which they are inserted, and should be applied one externally and the other internally, to the limb. They should be fastened by a sufficient number of turns of plaster bandage to give the apparatus sufficient strength. The margins of the dressing in the neighborhood of the wound should be filled in with the antiseptic paste, and the antiseptic dressing applied to the wound as usual.

The form of interrupted plaster dressing, called by Szymanowski the honeycomb plaster dressing, may be easily improvised and applied in cases where extensive or multiple injuries exist. It consists of applying first as many separate plaster rings as the required interruptions make necessary, and then connecting these with narrow wooden strips, which are fastened to the plaster rings by other turns of the plaster bandage until the whole is consolidated with sufficient firmness to secure absolute immobility to the enclosed parts. The interspaces between the wooden strips permit a thorough dressing of the wounds and frequent renewal of the same.

If either the fenestrated or interrupted plaster dressing, in any form, is used, it must remain in place till the wound is covered by skin. As by antiseptic methods of treatment this will have happened long before consolidation of the fracture has occurred, a close plaster dressing should be substituted for the open one during the period that will yet remain before firm union of the bone is accomplished.

PART II.

SPECIAL WOUNDS.

SECTION II.

WOUNDS OF TISSUES COMMON TO ALL PARTS OF THE BODY.

CHAPTER XVI.

WOUNDS OF MUSCLES—TENDONS—NERVES.

Wounds of Muscles—Difficulties of Coaptation—Position—Bandaging—Suturing—Rest—Protection from Sepsis—Subcutaneous Ruptures—*Wounds of Tendons*—Healing of Subcutaneous Wounds—Difficulties of Open Wounds—Importance of Antisepsis, Protection, and Rest—Suturing Tendons—Lange's Case—Pauly's Case—*Wounds of Nerves*—Importance of Approximation of Divided Ends—Methods of Approximation—Suturing Nerves—Tillman's Statistics—Results reported by Page—Pye's Case—Page's Case—*Application of the Nerve-suture*—Direct Nerve-suture—Peri-neural Suture—The Suture Material—Conditions Requiring Nerve-suture—Neuroplasty—Tubular Suture—Contra-indications—Requisites to Success.

WOUNDS OF MUSCLES.

The retractile nature of the muscular tissue, by its tendency to cause wide separation of the divided ends of an injured muscle, occasions special difficulties in the treatment of wounds of these organs. In order to bring the wound-surfaces into apposition it is necessary that the part be placed in a position of complete relaxation, in which it must be kept during the course of the healing, till firm union has taken place. When it is a muscle of one of the extremities that is wounded, the continued relaxation of either portion will be promoted by the application of two roller bandages, applied in opposite directions, each beginning at that part of the muscle most distant from the wound, and approaching the wound as they are applied. Thus the contraction of the fleshy fibres may be controlled, and the approximation of the retracted ends favored.

The permanent functional impairment which is entailed by a failure to secure approximation and union of the divided ends of a muscle, lends importance to every means which can be adopted which will prevent such failure. Sutures should be applied—sutures of relaxation and of coaptation—the deeper sutures being carried through nearly the whole thickness

of the muscle. Rest by means of position, compression, and immobilization should be maintained with great care. When adequate protection against the causes of inflammation is neglected, approximation by sutures will be of little value, since the softening of the tissue, even to some little distance from the surface of the wound, consequent upon the inflammatory changes, will cause them to be easily torn out. Every precaution, therefore, of wound-cleanliness and of antiseptic dressing should be observed in the care of this class of wounds, to prevent the production of inflammatory or septic disturbances.

In the treatment of subcutaneous ruptures of muscles, when the muscle is one whose function is of importance, and is so situated that it is accessible without endangering more important organs in the operation, the protection of the unbroken skin should be sacrificed, and the wound converted into an open one, in order that the more important indication of bringing the retracted ends into coaptation by sutures may be accomplished. Should the edges of the wound across the muscle prove to be ragged, they should be trimmed sufficiently to permit of close apposition of the surfaces.

Subcutaneous muscular ruptures which are too deep seated, or which are complicated with other injuries that make their exposure by incision inadvisable, should be treated in accordance with the general methods described for the management of subcutaneous injuries.

WOUNDS OF TENDONS.

Approximation of the divided ends of a severed tendon must be favored by placing the part in that position which will fully relax the attached muscle ; appropriate means of immobilization and compression must then be used to prevent retraction and separation during the period of repair. The healing of subcutaneous wounds may be expected to progress undisturbed without other treatment, if these precautions be observed. Divided tendons, in which the injury has been accompanied by a simple punctured wound of the skin, as in the operations of tenotomy for orthopædic purposes, in which immediate occlusion of the external wound is accompanied by its healing by primary union, require the same simple treatment as if the wound had been absolutely subcutaneous from the first.

Open wounds exposing divided tendons present conditions especially favorable for the development of wound-disturbances, which conditions are still more aggravated in those cases in which a synovial sheath for the ten-

don is likewise opened. The retraction of the tendon-fragments prevents approximation and primary union, and leaves recesses for the accumulation and retention of secretions; the synovial sheaths offer favorable material and surfaces for the development of sepsis, and in their absence the connective-tissue that ensheaths the tendon affords a favorable tissue for the development and extension of phlegmonous inflammations. A strict observance of every detail of wound-cleanliness and disinfection is therefore necessary in the treatment of open wounds of tendons. Perfect arrest of hæmorrhage must be accomplished. The primary cleansing of the wound must be scrupulous, and adequate means for drainage must be provided. The ends of the divided tendons must be sought for, and their coaptation effected and maintained by sutures. It is less essential what the exact kind of suture it is that is employed, than that it be aseptic and of sufficient durability to maintain the coaptation till the union shall be firm. The suture should be passed through the tendon sufficiently far from its edge that it shall not be easily torn out. The external wound should then be closed, with due attention to drainage. Protective dressings and provisions for rest should be applied with minute care.

The treatment of wounds involving tendons, in which suppuration or inflammatory disturbances have already declared themselves must be conducted in accordance with the methods governing the treatment of such wounds in general. The suture of the tendon-fragments will have to be abandoned or omitted in such cases, and their direct union left to be accomplished by operative measures at a later period, after cicatrization of the wound has been effected.

When marked impairment of function remains long after the wound has healed, as the result of a gap which persists between the retracted ends of a divided tendon, whether the original injury have been a subcutaneous rupture or an open wound, the parts should be exposed by a free incision, the ends of the tendon-fragments freed from any new attachments, freshened, and, having been brought, if possible, into coaptation, sutured together. If the end of the proximal fragment cannot be found, or cannot be brought down to the distal fragment, the freshened end of the latter may be attached to a contiguous tendon, with the result of restoration of some power over the supplied part. If the matting of the end of the distal fragment in the cicatricial tissue at the point of injury is so extensive as to make its isolation unwise, the end of the proximal fragment may be brought down and likewise attached to the cicatrix, with the

result of increasing the amount of voluntary control over the parts beyond. As an example of the results which may be obtained from exposure and suture of divided tendons subsequent to the healing of the primary wound, the following case may be quoted: At the meeting of the New York Surgical Society of March 13, 1883, Dr. F. Lange presented a lady patient who, about two months previously, had fallen from a considerable height, and sustained a wound, cutting the tendons of the extensor muscles of the left forearm. He saw the patient two weeks afterward, when the wound was almost healed, and there was extensor paralysis involving the third and fourth fingers, only the last two joints moving through the action of the interossei. About two weeks later Dr. Lange made a longitudinal incision, and found that three of the extensor tendons had been divided, namely, those belonging to the third and fourth fingers, and to the index finger. The extensor indicis proprius was not injured, for the action of the index existed. The divided tendons of the extensors were separated to a distance of almost one inch and a half. They were brought together and sutured with antiseptic silk. The hand was then put in a position of superextension, and an antiseptic dressing applied. The sutures were removed at the end of one week. The result was that the movements of the fingers could already be quite satisfactorily performed, and it was probable that improvement would still continue.

The results of the immediate suture of a divided tendon, with proper after-treatment, are exemplified in the following case, reported by Pauly,[1] of Posen. It is also quoted by MacCormac, in his Antiseptic Surgery.

A boy fell from the top of a hay wagon, with the left heel right across the blade of a scythe.

A wound four inches long, extended transversely from one malleolus to the other, completely dividing the tendo Achillis, and opening the ankle-joint from behind. The tuberosity of the os calcis, with the piece of tendo Achillis attached to it, about an inch in length, was completely severed from the rest of the bone, to which it remained connected by soft parts alone. Antiseptic treatment was adopted. The detached tuberosity was fastened in its place by a common nail, and while the foot was maintained in the equinus position, the divided surfaces of the Achilles tendon were united together by catgut sutures inserted alternately deeply and superficially into the substance of the tendon.

---

[1] *Centralblatt für Chirurgie*, January, 1878.

In nineteen days a complete recovery was accomplished, and one year afterward, the report states that the function of the limb was perfectly normal.

WOUNDS OF NERVES.

While it is true that, in general, wounds of nerves should be treated on the same general principles as wounds of other structures, yet special attention is demanded to the methods and results of attempts at securing approximation of the divided ends in those cases in which important nerve-trunks are severed.

The regeneration of nerve-tissue through a cicatrix, and thus the spontaneous restoration of the function of a nerve that has been divided, even when considerable loss of substance, or retraction from each other of the divided ends has been present, has been observed to occur with sufficient frequency to render not altogether hopeless any recent case of paralysis resulting from section of a nerve; as a rule, however, the re-establishment of the functions of a nerve never takes place when its extremities have been allowed to become separately cicatrized; but in such cases an after-history of abolished function, neuralgic and trophic disturbances is entailed. When, however, the ends of the divided nerve can be brought into early apposition, and primary union of the wound can be secured, speedy restoration of function in great part may be confidently counted upon.

The indication is imperative, therefore, to secure and maintain the closest possible approximation of the cut surfaces of a divided nerve during the healing of the wound, that the amount of cicatricial tissue may be reduced to a minimum, and that the more speedy and certain restoration of function may be favored.

A degree of approximation may be secured by the position of the wounded part, by keeping it in such a position that the nerve-trunk shall be relaxed, and by those means of approximation which may be applied to secure coaptation of the surfaces of the wound in general; but the intrinsic retraction of the fragments of the nerve-trunk itself will still cause, in most instances, more or less of a gap to remain between them.

In contused and lacerated wounds, and in wounds in which there is appreciable loss of substance, it is unlikely that even approximate apposition of the ends of divided nerves could be effected without the use of special means. The natural resource in such cases, in addition to the gen-

eral means of relaxation and approximation already referred to, would be to isolate the separated ends of the nerve-fragments, draw them down into apposition with each other, and keep them apposed by suturing them together.

The knowledge of the evil effects frequently due to punctures of nerves and to their inclusion in ligatures, the fear of tetanus and of inflammatory complications, has, however, rendered surgeons cautious in resorting to nerve-suture. A more frequent resort to it has, however, marked the practice of surgeons of late years; in none of the reported cases have untoward complications occurred, and the marked benefits secured by its practice have now established it as a regular surgical procedure, the neglect of which, in the cases calling for it, would be censurable.

In a paper devoted to the subject of wounds and suture of nerves, by Tillmans,[1] of Leipsic, in 1881, out of 42 cases of nerve-suture, in general, which he tabulates, in 22 cases the application of the primary suture is stated to have been made. In 13 of these the result, as regards restoration of function, is stated to have been successful; in one, only, unsuccessful; the remaining eight being classed as questionable. In eight other instances sufficient data for determining whether the suture was primary or not, is not given. Four of these resulted successfully, one unsuccessfully, and three were questionable. In 12 instances at various lengths of time after cicatrization of the wound had taken place, the separated nerve-ends were exposed by proper incisions, and their refreshed ends, having been brought together, were sutured. Of these cases of secondary suture, six resulted successfully and six are classed as questionable. Herbert W. Page,[2] of London, has related four successful cases of primary suture not included in Tillmans' tables, two from the practice of Mr. Favell, one from Mr. Pye, and one case of his own. More recently Mr. Page has reported[3] the ultimate results of two cases of secondary suture, one having been completely successful, the other but partially so.

The case of primary suture of Mr. Pye, and that of secondary suture of Mr. Page may be detailed as fair examples of the two classes of procedure. In the first instance, a lad, aged 14, caught his arm in a printing-machine

[1] *Ueber Nervenverletzungen und Nervennaht. Archiv für Klinische Chirurgie*, xvii. 1.

[2] The Immediate Suture of Divided Nerves. British Medical Journal, May 7, 1881, p. 717.

[3] Case of Secondary Suture of Ulnar Nerve Six Months after its Division. British *Medical Journal*, June 23, 1883, p. 1223.

and received a lacerated wound behind and on either side of the left elbow-joint, exposing the internal and anterior aspects of the capsule of the joint with the brachial artery, tearing the tendon of the triceps, and chipping off part of the internal condyle of the humerus. The median nerve was torn completely across. The ends of the nerve were brought together, as nearly as possible, by catgut sutures passed through the substance of the nerve and through its sheath. The wound was lightly dressed with carbolic acid, and the arm was placed in an angular splint. During the first week thereafter the motor and sensory paralysis appeared complete in the hand and in the muscles of the forearm supplied by the nerve. Then there began some pricking and tingling of the forefinger, soon followed by commencing power of flexion. The return of sensation, once started, progressed rapidly and was nearly complete by the end of the month. The ball of the thumb and the radial side of the middle finger remained insensitive throughout. The return of muscular power was fairly good, but was more difficult to estimate in consequence of the cicatrization of the wound.

The example of secondary suture which I desire to quote was the case of a man, aged 25, who six months previously had received a severe wound of the left wrist from glass, which was a month in healing. From that time he had extreme pain in the cicatrix, his ring and little fingers became bent and useless, and he was obliged to carry his arm in a sling. When admitted for treatment, the wound cicatrix was excessively tender, he had lost the power of extending the two last phalanges of the ring and little fingers, and, to a less extent, of the other fingers also, and the thenar and hypothenar eminences, together with the interossei, were markedly wasted. Sensation was very defective, though not entirely absent, in the ring and little fingers, more especially on their palmar surfaces. The whole hand, indeed, was somewhat anæsthetic and withered from disease. It sweated constantly and profusely; the little finger was blue and slightly swollen, and the nail was much misshapen.

April 4, 1881, Mr. Page cut down on the site of the ulnar nerve, and with much difficulty found the separated ends. The upper end of the lower portion was found turned downward and inward, and ended in thick cicatricial tissue on the under surface of the tendon of the flexor carpi ulnaris. It was not enlarged, and a transverse section of it, when freed from the cicatrix, showed the appearances of healthy nerve. The lower end of the upper portion was swollen to about three times its natural size, and ended in a firm bulbous nodule, which also was bound in cica-

tricial tissue. From this it was dissected, and a third of an inch had to be removed before the section looked natural. It was necessary to dissect the upper part of the nerve free for a couple of inches, before the two ends could be brought into comfortable apposition; they were then joined by three fine catgut sutures passed through both sheath and nerve. The wound healed by first intention. As early as the tenth day the anæsthesia was less marked. At the end of three weeks, sensation had decidedly improved, the cicatrix was free from pain, and some return of the power of extension of the last phalanges of the ring and little fingers was evident. At the end of twenty-two months, during the first year of which appropriate galvanic and faradic treatment had been persevered in, his hand was as useful as it had ever been. There was no sign of trophic disturbance; sensation was normal; there was no wasting; he, however, experienced occasional pain in the cicatrix on change of weather, and was unable to perfectly extend the last phalanx of the little finger.

Application of the Nerve-suture.—For the purpose of securing apposition of the two ends of a cut nerve, sutures may be introduced either through the substance of the nerve-trunk itself or simply through the connective-tissue that acts as a sheath to the nerve, including, perhaps, the neurilemma. The former constitutes "direct nerve-suture," the latter "indirect" or "peri-neural" suture.

Direct Nerve-suture.—This is the form of suture which has been resorted to in the greater number of the published cases of nerve-suture. By means of a fine needle the thread is made to traverse the body of the nerve and embrace its substance in the knot which is tied. By some the nerve has been pierced through and through; others have brought out the thread at the lower, or at the middle part of the cut surface. The latter method is more likely to secure accurate and steady coaptation, but if there is any strain upon the suture, it will be more quickly cut out. In the former method greater care will be required to obtain exact adjustment and avoid angular deviation of the ends when the knot is tied, but it gives a greater security against subsequent gaping by retraction. One thread only will suffice, unless a large trunk, as the great sciatic, is under treatment.

Peri-neural Suture—The insertion of the sutures through the peri-neural connective-tissue, when, by so doing, sufficient traction on the nerve-fragments can be effected to overcome the gaping at the point of division, recommends itself by the fact that by its practice the nerve-bundles neither receive injury by the needle puncture nor by the after-strain of

the thread. For its application two sutures are required, one at either side of, and close to, the nerve. When the sutures are drawn up and carefully knotted, coaptation of the cut surfaces of the nerve may be obtained with even more accuracy than when the direct suture is employed. The results obtained by the use of the indirect suture have been very satisfactory. In seven of the cases reported by Tillmans, was this method of coaptation used, with a successful result in all but one.

Both the direct and the indirect methods may be employed in the same case, when the conditions seem to require it, the one great indication to be met being exact and stable coaptation of the cut surfaces.

The Suture Material.—The choice of the thread for the suture is of importance, for the highest success of the suture can be obtained only by securing union by first intention. No material should be used for the suture which will interfere with primary union of the wound. Aseptic catgut, silk, or silver wire may be used, but the catgut is to be preferred, as by its subsequent spontaneous absorption it is not so likely to become a source of future irritation. By the use of catgut, and the indirect method of suture, no hesitancy need be felt in the application of the suture in every case of complete division of a nerve-trunk.

Conditions Requiring Nerve-suture.—A recent wound, in which a nerve-trunk has been severed, requires the separate suturing of the ends of the divided nerve, as one of the elements of securing proper "wound-apposition." Some latitude of practice and judgment may be allowed in cases in which the external wound is quite restricted, and in which little tendency to retraction may be supposed to exist, and by position and the general measures instituted for the approximation of the wound-surfaces, its primary union is probable.

When the external wound is considerable, even though the retraction of the divided ends of the nerve is not great, the suture should be employed.

When decided separation of the divided ends of the nerve exists, either as the result of retraction or of loss of substance, the suture must not be omitted. The amount of separation which can be overcome, so that the ends of the nerve-fragments can be again apposed, may be considerable.

Nélaton brought together the ends of the median nerve after having exsected two and one-third inches of its continuity; von Langenbeck obtained union between fragments of the great sciatic nerve that had been separated by a distance of two inches. If, however, it is found impossible

to bring the divided ends together, one of four expedients may be adopted. First, if several nerves have been divided, the expedient of Flourens may possibly be resorted to, that of uniting the lower end of the most important nerve to the upper end of another. Second, if such less important nerve be not already divided, if it be accessible, a sufficient portion of its surface may be freshened, and the lower end of the divided nerve sutured thereto, virtually grafting it in. A successful instance of this kind is reported by Marchand,[1] from the clinic of Deprès. A lacerated wound of the left arm had torn the median nerve. Deprès found it impossible to bring the central end of the torn nerve down so as to suture it to its corresponding fragment. He therefore exposed the ulnar nerve, and having separated its fibres by tearing them apart with a pair of dressing forceps, into the interspaces inserted the fibres of the peripheral end of the median nerve. The procedure was crowned with success, and the patient recovered a useful hand.

The two remaining expedients are those of "neuroplasty," or transplantation of nerve-tissue to fill the gap, and of "tubular suture." These are still matters of physiological experiment, but deserve mention in this connection. They are referred to by Nicaise,[2] as follows: "Gluck, of Berlin, has resected in chickens three or four centimetres (1 to 1½ inch) of the sciatic nerve, which he has replaced by a piece of the sciatic nerve of a rabbit, sutured at both of its extremities. The chickens thus operated upon walked as well as those upon which direct suture of the sciatic had been practised, while section of the sciatic without suture or autoplasty produced a paralysis of this nerve which was still complete at the end of ten weeks. This procedure is yet in the domain of physiology. When the separation of the ends of the nerve is considerable, and they cannot be brought in contact, the *tubular suture* of Gluck and Vaulair may be tried. The aim of this is to prevent the obliteration of the space which separates the two segments by the interposition of a Neuber's osseine tube. Gluck has only obtained negative results, but Vaulair has seen, he says, after a delay of four months, the regeneration of a nerve-trunk measuring five centimetres (2 inches). He has determined that the regeneration is effected by centrifugal granulations arising from the central end, as has

---

[1] *Gazette Hebdomadaire de Médecine et de Chirurgie*, 1876, No. 5.

[2] Injuries and Diseases of Nerves. International Encyclopædia of Surgery, vol. iii., p. 624.

likewise been shown by Eichhorst, Ranvier, and Hahn. He adds that a small portion only of the new fibres unite with the degenerated fibres of the peripheral end."

When the section of the nerve is the result of a contused wound, the disintegrated or badly contused portions of the exposed ends should be resected until surfaces capable of primary adhesion are reached, which are then to be brought together. In cases of severe contusion of a nerve-trunk, without actual solution of its continuity, the propriety of exsecting the contused portion and suturing the extremities which remain, is worthy of consideration in view of the frequent, prolonged, and severe loss or disturbance of function following nerve-contusions, and the good results obtained by nerve-suture.

The suture is contra-indicated when the wound is no longer recent, but has begun to suppurate. In such cases, general measures of approximation must alone be relied on until cicatrization has taken place, after which, if necessary, operation for secondary suture may be instituted.

The approximation and suturing together of the divided ends of a nerve should be done as early as possible after the wound has been inflicted. It is important that primary union be secured; minute observance of every requirement of wound-treatment should mark the care of a wound involving a nerve-trunk.

CHAPTER XVII.

WOUNDS OF BLOOD-VESSELS.

Importance of Wounds of Blood-vessels—Results to be Secured in Treatment—Difficulties—Obliteration of Vessels—Relations of Coagulum to Repair—Physiology of Repair—Apposition of Inner Serous Surfaces—Means of Compression—The Ligature—Ligation—Gross or Immoderate Violence in Tying a Ligature—Rules of Procedure—*Complications of Wounds of Blood-vessels*—Primary Hæmorrhage—Intermediary Hæmorrhage—Secondary Hæmorrhage—Diffuse Traumatic Aneurism—*Wounds of Veins*—Peculiarities—Phlebitis and Periphlebitis—Thrombosis—Effects of Septic Ligatures—Acupressure and Forcipressure—J. E. Pilcher's Case—Advantages of Aseptic Ligatures—Repair of Vein Wounds—Gross' Case—Langenbeck's Case—Lateral Ligation—Braun's Statistics—Necessary Precautions—Lateral Suture.

All wounds involve wounds of blood-vessels, and the indications for treatment which the resulting hæmorrhage presents have claimed attention in connection with each of the general classes of wounds that have been considered. There remain, however, certain special considerations with regard to wounds of these organs to which further examination should be directed.

It is impossible to exaggerate the importance of wounds of blood-vessels; the treatment which is demanded, when vessels of any size are involved, must be instantaneously applied, in default of which quick death is inevitable. It is the opinion of Lidell[1] that more lives are lost from the hæmorrhage resulting from wounds of blood-vessels, either directly or indirectly, than from all the other consequences combined which flow from wounds. In support of this assertion he states that of the slain in battle, of whom he had personal observation during our War of the Rebellion, a very large share, about one-half, possibly even more than that, perished by hæmorrhage from wounds of the large blood-vessels of the neck, chest, abdomen, groin, etc., or from wounds involving vital organs like the brain

[1] Injuries of Blood-vessels. International Encyclopædia of Surgery, vol. iii., p. 46.

and lungs, the bleeding whereof caused deadly compression of these organs before succor could be afforded.

The treatment, again, must be effectual for the permanent obliteration of the open orifices in the wounded vessel, otherwise renewed peril from the escape of blood will supervene.

The treatment of the wounded vessel should, if possible, be conducted in such a way as to avoid introducing sources of disturbance into the healing of the other wounded tissues; thereby, also, its own undisturbed repair will the most certainly be secured. The elements of treatment which wounded blood-vessels require do not differ from those required by other tissues. Hæmorrhage must be arrested, the wound must be cleansed and brought into apposition, protection against disturbance from without must be supplied, and rest must be secured until repair is perfected.

The practical difficulties which complicate the treatment of these wounds spring from the peculiar function and anatomical character of the organ. The blood-pressure within them is a constant force tending to separate the edges of the wound, while the escape of this vital fluid constitutes a danger which must be prevented at the sacrifice, if necessary, of the functional activity of the organ itself. The thin walls of the organ do not afford sufficient surface, when wounded, for securing perfect and reliable apposition of the edges of the wound, in antagonism to the pressure of the column of blood which they enclose, and to the intrinsic tendency to gaping from the contractility of its own tissue. Longitudinal wounds of veins, however, in many instances form an exception to this statement. The readiness with which the internal tunic of blood-vessels responds to irritation by the production upon its surface of plastic material, suffices, when taken advantage of, to supplement the reparative deficiencies of the cut surfaces. From this source granulation tissue is produced that by its organization obliterates that part of the vessel filled by it, and permits the undisturbed organization of the reparative material produced from the wound-surfaces themselves. The coagulum which forms within the last portion of the canal of a severed vessel, and blocks it up, not only serves as a temporary plug to prevent the escape of blood, but it stimulates the vascular tunic, with which it is in contact, to an increased cell-activity that results in new tissue that not only assists in forming a permanent seal to the vessel, but also invading the clot, substitutes for it cicatricial tissue that converts the now unused portion of the vessel into a fibrous cord. The result is a total loss to the economy of a portion of its

substance, and the permanent impairment of function of an organ. The importance of this loss and impairment will depend upon the importance of the particular vessel and upon the ability of other vessels to supplement the defects of the injured one by increased development and labor. Permanent impairment of function, œdema, and gangrene are not infrequent results of the obliteration of vascular trunks.

The presence of a coagulum, however, is not essential to the inauguration of the processes by which a wounded vessel is to be sealed up, and its presence is an embarrassment, rather, to the repair when the needful support and rest to the part can be secured while its repair is in progress. The effects of the original traumatism by which the vessel has been wounded suffice to stimulate that portion of the internal tunic adjacent to the wound to the needed nutritive activity, and if the effort of the surgeon is successful in keeping the proliferating surfaces of this tunic in contact until firm adhesion has taken place by the organization of the new material supplied by it, the best result will be obtained.

Apposition of the wound-surfaces, therefore, in the case of wounds of the blood-vessels, with exceptions that will be mentioned, should be substituted by apposition of the surfaces of that part of the inner tunic of the vessels which is immediately adjacent to the wound.

The treatment of wounded blood-vessels in this respect involves the same principles as those which hereafter will be found to govern the treatment of wounds of thin-walled membranous organs, as the pericardium, alimentary canal, or urinary bladder, the walls of which present on one side a serous surface, the apposition of which, rather than of the wound edges themselves, affords the most rapid and secure means of closing a penetrating wound of their substance.

Some means of compression will be required in every case for keeping the inner surfaces of the vessel in contact until firm adhesion, adhesion firm enough to resist the impulse of the blood-current, and the tendency to gape of the walls of the vessel itself, has taken place. This will be afforded by the means which have at once been adopted for restraining the escape of blood. The various resources which are at the command of the surgeon for this purpose have already been considered at length in the chapter devoted to arrest of hæmorrhage (Chapter VI.). Whatever method, however, may have necessarily been adopted in the emergency of the primary hæmorrhage, if the wounded vessel prove to be of a size that its prolonged compression is necessary, it should be substituted,

at the earliest practicable moment, by the application of an aseptic ligature.

The ligature discharges two functions, that of a means of hæmostasis and of apposition. In its application for the first purpose, it is essential that it should be drawn with such tightness that its grasp of the vessel shall be so firm that it shall not slip off accidentally. It is not necessary, however, that it should rupture any of the coats of the vessel, or that the distal portion of the vessel should be strangulated.

The purposes of apposition require a force of ligation no more powerful than the preceding. The additional traumatism of ruptured coats is not required for exciting or reinforcing the reparative effort, while such application of a ligature as shall determine a process of ulcerative inflammation in the tissues grasped by it, is to be deprecated as the possible determining cause of secondary hæmorrhage.

In this connection I cannot refrain from repeating the following exclamation of Gross:[1] "Nothing is more unseemly, or more truly reprehensible, in a surgeon or his assistant, than to pull a ligature by fits and jerks, or so violently as to break it, or, perhaps, lacerate and tear off the artery itself. With a little care and gentleness, a comparatively weak ligature may be thrown around a vessel so as to answer the intention most fully. I dwell upon this point with some degree of emphasis, because it has happened to me to witness a very unusual number of these Herculean feats with the ligature, the men often pulling as if they had hold of a rope and piece of wood, instead of a delicate thread and artery.

It is important, as the first step in the treatment of a wounded blood-vessel—it being understood that in all cases vessels whose size or relations are such as to require special treatment are being referred to—that full exposure of the wound in the vessel is secured. In the case of superficial wounds, and of deeper wounds with extensive division of the more superficial structures, such exposure of a wounded vessel is easily and spontaneously accomplished. In deep wounds, with restricted external wound, as in punctured and gunshot wounds, this full exposure of the wounded vessel is equally imperative. Plugging of such a wound with tampons, or compression of the main trunk on its cardiac side, if it be an artery, may be resorted to as means of temporary arrest of bleeding; but as soon as the conditions permit the methodical dressing of the wound, the vessel must

[1] System of Surgery, 1882, i., 659.

be laid bare at the injured point, and permanent ligation be practised. For this purpose free incisions must be made through the skin and overlying tissues, always making them of sufficient length so that the structures at the bottom of the resulting wound shall be distinctly exposed and readily accessible to manipulation. As Esmarch remarks (International Medical Congress, London, 1881), "when life is concerned, it matters little whether the incision be an inch or a foot long; as, if it succeed in checking hæmorrhage, and be conducted thoroughly aseptically, a long incision heals just as well as a short one."

Care to first render the limb bloodless, in the case of wounds of vessels of the extremities, by the use of an elastic bandage, after the method of Esmarch, will greatly facilitate the making of the required incisions. In other cases, a finger thrust into the wound so as to reach and compress the wound in the vessel, will both control the hæmorrhage for the time being, and will serve as an invaluable guide for the incisions. As the incisions are made, all blood-clots should be thoroughly and carefully removed by sponging and scraping, and perfect cleansing of the wound from fluid blood and débris of every kind should be done. When the wound in the vessel has been found and exposed sufficiently to enable its entire extent to be seen, the vessel must be isolated, and a ligature applied to a healthy part of it both above and below the wound. The ligatures must be aseptic—catgut or silk—and after having been securely tied, should be cut off close. If, by misfortune, no aseptic material for ligatures can be obtained, necessity will compel the use of an ordinary thread. In this case, one end having been cut off near the knot, the other should be brought out at the most dependent angle of the wound.

Esmarch calls attention to the difficulty that may be experienced in distinguishing veins, when bloodless and collapsed, from cords of connective-tissue. As a means of overcoming this, he advises the preliminary formation of a reservoir of blood below the wound by placing a ligature around the hand, for instance, before applying the elastic bandage to the arm. Afterward, on elevating the limb and removing the ligature, the blood flows out of the injured vein, if the vessel have been such.

If the vessel have been only partially divided by the original injury, after the ligatures have been applied on either side of the wound, the division should be made complete, and the two ends allowed to retract.

The direction to apply a ligature to the distal as well as the proximal side of a vessel-wound is especially applicable to wounds of arteries, and is

to be observed whether the distal extremity bleeds when exposed or not. If left unsecured, imminent risk is incurred from intermediary hæmorrhage as the full natural force of the circulation begins to be again felt, or from secondary hæmorrhage after a more free collateral circulation shall have become established.

The same reasons contra-indicate the practice of ligating the trunk of the artery above the wound, except in those instances in which the bleeding artery is inaccessible, as the internal maxillary, and, in some instances, the lingual.

In the treatment of wounds of small vessels lying at the bottom of deep cavities, and, in more superficial wounds, where a general bleeding from many small vessels persists, in which the application of ligatures is impracticable, the methods which have been described are impracticable, and the use of the actual cautery, and of tampons is necessitated.

Every effort should be made to secure primary union in wounds that are complicated by wounds of important blood-vessels. The greatest safeguard against the occurrence of secondary dangers from wounds of the vessels is secured by preventing disturbances in the healing of the general wounds of which they form a part. Every precaution against sepsis which is within the command of the surgeon should be practised in the dressing and after-treatment of these wounds.

COMPLICATIONS OF WOUNDS OF BLOOD-VESSELS.

The complications which are so especially related to wounds of vessels as to demand consideration here, are the losses of blood which are liable to attend these wounds. Those losses which follow immediately upon the infliction of the injury constitute *primary hæmorrhage ;* those which attend the period of reaction, constitute *intermediary hæmorrhage ;* and those which take place after the establishment of suppuration constitute *secondary hæmorrhage.* The extensive effusions of blood which follow upon the subcutaneous rupture of large blood-vessels, known as *traumatic aneurisms,* demand, also, some consideration.

Primary Hæmorrhage.—The treatment demanded for the control of this complication has been fully considered in the first part of this treatise, Chapter VI., to which reference should be made.

Intermediary Hæmorrhage.—The treatment of intermediary hæmorrhage must be conducted on the same principles as those which guide the treat-

ment of primary hæmorrhage. Its occurrence is an evidence of the inefficiency of the means which had been previously instituted, and would hardly take place in any case if the directions which have been given for the full exposure of wounded vessels, their careful ligation in a sound part of their structure on either side of the wound, the complete division of the vessel, if previously but partially divided, and the removal of coagula and débris from the wound. It is impossible to dwell with too much stress upon the importance of care and thoroughness in the application of the first dressing as a preventive of subsequent complications. This is illustrated by the list of causes of intermediary hæmorrhage which the medical historian of the War of the Rebellion gives as discernible in the cases, seventy-seven in number, which appear in the records of the Surgeon-General's office of the army.[1] The report states that "the earlier cases of hæmorrhage were due to the force of the blood-current in the returning circulation during reaction; to commencing inflammatory action, in which the swelling had been sufficient to force out the protective coagulum; to weakened arterial walls, and to a depraved condition of the blood in persons suffering from exhausting or depressing diseases. Not unfrequently the hæmorrhage of the earlier days had its source in the injury of some vessel of considerable size, unnoticed in the primary examination of the wound. Cases have been cited in which no excessive hæmorrhage was noticed until attempts were made to effect the removal of a lodged missile or foreign body, which had prevented bleeding by acting as a plug or tampon." The first three causes in this list are the result of failures to primarily expose and ligate the vessels. The last two to want of thoroughness in the primary examination of the wound. Other frequent causes of intermediary hæmorrhage, such as the inability of the vessel to retract by reason of its incomplete division, the imperfect compression of the vessel by a large coagulum which has been permitted to accumulate over it, acting the rather as a poultice upon it to keep it relaxed, and disturbance of the parts by muscular spasm, motion, or external traumatism, all alike are examples of infractions of the primary principles of wound-treatment.

The occurrence of intermediary hæmorrhage demands at once a new dressing of the wound, *ab initio*. It must be opened, enlarged if necessary, cleansed, explored, the vessels secured as already described, and its primary

---

[1] Medical and Surgical History of the War of the Rebellion. Part Third, volume ii., Surgical History, p. 809.

dressing and after-treatment conducted scrupulously in accordance with the general principles and methods of wound-treatment already described.

Ligation of the main trunk, the use of the actual cautery and the tampon are resources to be used in conditions noted on a previous page in this chapter.

Secondary Hæmorrhage.—Under this head are to be embraced all losses of blood from wounded vessels occurring after the establishment of suppuration. Referring again to the "Medical and Surgical History of the War of the Rebellion" (*loc. cit.*), we find the statement that by far the greater number of cases of secondary hæmorrhage are due to the separation of a slough, the result of a contusion of the walls of the vessel and the inflammatory action consequent upon it. Identical in nature with this class of cases is that group in which the hæmorrhage takes place where the ulceration of the vascular coats, produced by the constriction of an irritating ligature, is accomplished, without the previous obliteration of the adjacent portion of the vessel by adhesive inflammation.

Yet other cases have their origin in the breaking down of adhesions, or the progressive ulceration of tissue due to the changes effected in the wound by destructive inflammatory and septic processes.

Neglect to secure, by ligature, the distal orifice of a severed vessel may be the cause of a later hæmorrhage, after the collateral circulation shall have become sufficiently free to restore the strength of the blood-current in that portion of the vessel.

Faulty application of the ligature in the primary dressing; subsequent increase of blood-pressure as the result of venous thrombosis, or inflammatory engorgement, or improper position of the wounded part; interference with repair by muscular spasm, motion, or external traumatism; constitutional conditions that interfere with repair; these should be added to the list of causes that may determine a secondary hæmorrhage.

This statement of the causes of secondary hæmorrhages is a record of failures either to institute or to carry out the primary principles of wound-treatment. It enforces the injunction already given to observe with scrupulous care, in the treatment of wounds involving the opening of large blood-vessels, every precaution which shall prevent the access of disturbance in its repair, and shall foster the most rapid union throughout its extent.

The appearance of secondary hæmorrhage from a wound, even though it at first be small in amount, should at once engage the effort of the sur-

geon for the application of efficient means for arresting it and preventing its renewal. Only the most radical measures should be employed. Even though the hæmorrhage, either spontaneously or as the result of superficial applications, have ceased at the time, its recurrence again and again is certain, unless adequate proceedings for its control be at once instituted. The opening in the vessel must be sought for and exposed, and ligatures placed on both its distal and proximal sides at points where the vascular tissue is sound. This rule is subject to those exceptions only which have already been noticed in connection with the treatment of intermediary hæmorrhage.

Diffuse Traumatic Aneurism.—The same principles which are applicable to open wounds apply also to the treatment of rapidly extending effusion of blood from subcutaneous wounds of large blood-vessels. Nor should the treatment be delayed till the effusion has attained a threatening magnitude. The surgeon should proceed at once to expose the wound by external incisions, ligate, cleanse, dress, and immobilize, as in the case of other wounds.

WOUNDS OF VEINS.

In some instances the treatment of wounds of veins may justifiably vary from that which would be imperative for wounds of arteries of the same importance. Such variations are dependent upon the differing anatomical and physiological conditions of the two classes of blood-vessels, and also upon the different course which, in consequence, their repair may take.

The tendency to gaping of the wound, in the case of a vein-injury, is less than in a similar wound of an artery; the greater thinness of the walls of veins causes them, as tubes, to be more flaccid and to collapse spontaneously when empty, while the more languid and even flow of blood through them, and the freer collateral circulation, reduces greatly the force with which they are distended by their contents. From these circumstances apposition of divided surfaces is more readily secured and maintained in them, as a class, than in similar wounds in arteries, and the provisions of "rest" during repair are less likely to be violated. As a consequence, the repair of vein-wounds is often rapid and perfect, and union of incomplete wounds may even be accomplished in many instances without obliterating the canal of the vessel. Such a result, as a rule, is obtained in cases of longitudinal wounds of superficial veins, when the

treatment is confined to the application of simple external compression. The pressure of the compress suffices to exclude the column of blood from the wounded region until adhesion of the edges of the wound in the wall of the vein has taken place. Upon the withdrawal, then, of the compression, the blood renews its course through its previous channel.

In the case of wounds partially dividing a large and deep-seated vein, the size of the vessel and the flaccidity of its walls may permit the edges of such an incomplete wound and some of the inner tunic adjoining to be brought together and held in apposition by ligatures, sutures, or clamps, until firm adhesion has taken place, without interruption to the flow of blood through the vein at any time. No such thing is possible in the case of any arterial wound.

The direction of the blood-current in the veins toward the heart, and the continually increasing calibre of the channels through which it passes cause the occurrence of disturbances of repair in wounds in which veins are involved, or even exposed, to be attended with special dangers, either from dislodgement of a loosened clot or mass of fibrinous exudate, or from the production therein of more liquid and septic secretions that flow into and mingle with the general mass of the blood.

The loose connective-tissue in which veins are embedded, and which forms for them a kind of sheath, has been observed to afford most favorable conditions for the development and diffusion of septic phlegmonous wound-inflammations, in the course of which the tunics of the vessels themselves become involved, and disastrous phlebitis may ensue.

Mr. Benjamin Travers, in his essay on "Wounds and Ligatures of Veins," which was published in 1811, seems to have been the first to draw special attention to the dangers attending injuries of veins. He speaks of the "fatal catalogue of tied veins," and says that he has observed something like that superstitious alarm which is excited by events that we do not expect and cannot explain, when such a catalogue is compared with the generally successful cases of tied arteries. In the period immediately preceding the time when Travers wrote, there had been an entire absence of apprehension of danger in dealing with veins, so that, in the language of that writer, they were attacked with singular rudeness, pricking, cutting, tying, and burning them, without ever adverting to any other than the mechanical effects of such operations upon the diseases for which they were instituted.

This author was successful in awakening attention to the fact that dis-

astrous inflammatory complications often followed injuries of veins; that they sometimes followed a puncture, sometimes a division, a ligature encircling the tube, or including only a part of it; or that they sometimes arose spontaneously from an inflamed surface, of which the vein formed a part. The practice of phlebotomy, though involving only a simple longitudinal wound of a superficial vein, by the great frequency with which it was performed, afforded many examples of the accidents that might follow such wounds. Trousseau and Pigot, in 1827, testified[1] that every year they witnessed fatal inflammatory complications supervening upon phlebotomy. By many surgeons veins came to be regarded as vessels especially intolerrant of interference, and prone to the development of unexpected and uncontrollable complications. Ligation of veins, in particular, became considered as hazardous. Many of the surgical writers of the second quarter of the present century, including Roux, Lisfranc, Langenbeck, Miller, and Pirogoff, taught that it was attended with great danger, and to be avoided by all possible means. Dupuytren[2] spoke of phlebitis as "that inflammation so grave, so difficult to master, which has caused so great a number of persons to perish whose veins have been ligated." Chassaignac[3] taught that ligation was one of the most dangerous operations of surgery, and more recently, Erichsen,[4] that the application of a ligature to a vein "should, if possible, always be avoided."

A numerical majority of surgeons, however, have always held that the dangers of the ligation of veins were not sufficiently imminent to prevent its adoption as a measure of convenience in the treatment of a wound.

No difference of opinion has existed, however, as to the hazards attending the ligation of veins whose tunics were diseased, as in the case of varicose veins.

The occurrence of thrombosis and suppurative peri-phlebitis has been observed as particularly likely to be provoked in instances in which veins have been contused or denuded. In three instances, one surgeon—Ollier, of Lyons—is reported[5] to have seen death follow in from eighteen to thirty-six hours after the beginning of a thrombosis complicating a wound of this character. From this experience he concluded that extensive denuda-

[1] *Archives Générales de Médecine*, 1827.

[2] *Leçons Orales de Clinique Chirurgicale*, 1839, t. iii., p. 251.

[3] *Traité Clinique et Pratique des Operations Chirurgicales*, t. i.

[4] Science and Art of Surgery, 1878, vol. i., p. 278.

[5] Nicaise: *Des Plaies et de la Ligature des Veines*, 1872, p. 42.

tion of a vein is more dangerous than ligation; and that in cases in which immediate union is not obtained after such denudation, when sloughing of the flaps that cover the veins occurs, when, in a word, the veins remain exposed at the bottom of a suppurating wound, all the accidents of an extensive and progressive thrombosis are likely to occur. These complications, however, are not the inevitable consequences of denudation and contusion, for such injuries, in the greater number of instances, progress to recovery without their development.

Physiological experiment has fully demonstrated that the tunics of a vein do not possess a special intolerance that renders them liable to destructive inflammation more quickly and upon less irritation than other tissues. The more frequent connection of wounds of veins, than of their companion vessels, the arteries, with diffuse suppurative inflammations and profound and rapid general intoxication, is not a myth, nevertheless. It results from the readiness with which the connective-tissue that ensheathes the veins permits the progressive invasion of micro-organisms, and from the fact that the resulting peri-phlebitis determines the formation of coagula in the involved vein, which, in their turn, are likely to be speedily invaded by micro-organisms, and thus become converted into poison-dépôts, from which ptomaines, pus, and emboli are discharged directly into the circulation.

These dangers require to be considered, and to engage the careful effort of the surgeon for their prevention in all cases of wounds of veins.

The effect of the constriction of a vein by a ligature does not introduce any new danger into the wound. The evil effects which have been noted as prone to occur in wounds in which ligation of a vein has been performed, arise only in those cases in which the material of the ligature is irritating, and is so applied as to become the means of the introduction or retention of septic matter in the wound. Whenever an ordinary ligature is applied, the constricting thread is an irritating foreign body in the wound, and invariably excites along its track an inflammation which persists until its removal is permitted by the division, by ulceration, of the walls of the constricted vein—a period of time extending upon an average from one to two weeks, according to the size of the vein. Union by first intention is thus prevented, along the track of the ligature at least. The thread, saturated with the secretions of the suppurating sinus which it has created, becomes the best media for transmitting septic germs to the deepest part of the wound. The irritation of its presence puts an additional strain upon

the resisting power of the tissues among which it lies, and to this extent lessens their ability to resist invasion when septic germs find access to the wound.

The natural resisting power of the tissues is sufficient to limit, in the great majority of cases, the amount of disturbance resulting from an ordinary ligature to a circumscribed inflammation, which simply mats together the tissues adjacent to the ligature, and confines the destructive processes to necrosis of the tissue grasped in the loop of the thread. But in cases in which original defective resisting power exists, as notably in tissues whose nutrition has been interfered with by the varicosity of their veins, and in those in which some general cachexia pre-exists, an unchecked diffusion of the disturbances introduced by such a ligature would be likely to take place.

These considerations, as to the sources of the disturbances which have been observed to complicate vein-wounds, show the importance of eliminating them, not only in cases where veins already diseased exist, but also in all cases in which vein-wounds demand special means for the control of hæmorrhage and the maintenance of the walls in apposition. They justify the dread of ligation which has been felt by many surgeons, practised, as it has been, with an irritating thread, and they emphasize the importance of employing substitutes for such ligatures, so that full compliance with the requirements of surgical cleanliness and of wound-protection may be accomplished in the treatment of this class of wounds.

Acupressure and forcipressure both present great advantages over the common ligature as methods for controlling venous hæmorrhages, and few conditions will be found in which one or other of them may not be substituted for the ligature. The retention of the compressing needle or forceps is rarely necessary for a longer period than a few hours. Their smooth metallic surfaces do not irritate the wound; they may be enclosed in the antiseptic protective material that may be available for dressing the wound; and their early withdrawal removes the mechanical obstacles to primary union that they cause during their residence in the wound.

The value of forcipressure is illustrated by the following case:

Case.—*Wound of Internal Jugular Vein—Lateral Forcipressure—Recovery.*—In November, 1881, W. B., aged about 45 years, stabbed himself in the neck with a small dagger. The weapon was thrust into the right side of the neck, passed through the sterno-cleido-mastoid, grazed the internal jugular, in which it inflicted a small lateral wound, and finally pene-

trated the trachea. The wife, who was at his side in a moment, restrained the hæmorrhage by throwing her arm around his neck so as to compress the wound. Dr. James E. Pilcher was at the side of the patient in a few minutes. He enlarged the wound sufficiently to identify the vessel and expose the opening into it, which was a simple slit in its anterior wall, a quarter of an inch in length. He first applied a lateral ligature; but extension of the neck, caused by the falling back of the patient's head, as he was being placed in bed, caused this to slip off. Hæmostatic forceps were then applied, which, perfectly controlling the hæmorrhage, were left to produce permanent obliteration of the wound in the vein. On the second day thereafter they were removed. No further hæmorrhage took place. The wound healed by granulation, and a perfect recovery was accomplished.

In this case the forceps were kept *in situ* for a period of about thirty-six hours; but in most cases in which I have used them, as in wounds of veins in the axilla or in the neck, I have been able to remove them in a much shorter time.

In general, however, a more excellent way still is available to the surgeon in dealing with wounded veins. For, as acupressure needles and hæmostatic forceps excel the ordinary ligatures, so they, in turn, are excelled by the aseptic animal ligature and antiseptic protective dressings, by which, with a perfect hæmostatic, easily and universally applicable, that provokes no irritation by its presence in the tissues, and that is spontaneously removed by absorption when no longer needed, security is also guaranteed against the access from without of agencies that might disturb repair. By the use of such an aseptic ligature, it becomes possible to avoid the sources of disturbance that have thus far been recognized in wounds of veins, and to make the application of a ligature safe in all cases.

For the purpose of obtaining more definite data upon which to base the employment of the ligature in treating vein-wounds, I made a number of experiments during the year 1882 upon goats, using aseptic catgut. My experiments included three ligations of the internal jugular vein, and two of the femoral vein.[1] Union by first intention of the operation wound was secured in each instance. As the result of these operations I secured specimens illustrating the condition of repair upon the second, fourth, ninth, fourteenth, and twenty-fourth days after ligation. Examination of them demonstrated that marked proliferation of the tissue-cells of the tunica interna had been excited, the activity of this proliferation being

[1] The Use of Ligatures in Wounds of Veins. Medical News, Phila., 1883, xlii., 278.

greater as the point where the vein walls were constricted and approximated by the ligature was approached. The accumulation and confluence of the mass of cells in the cul-de-sac formed by the vein-constriction, the subsequent extension of capillaries into them, and the consequent conversion of the new tissue into connective-tissue, were the successive steps by which permanent closure of the tied veins was effected. In none of these experiments did a thrombus form on either side of the ligature, except in one case, in which special effort was made to secure one by applying a second ligature to the vein, swollen with blood, a little more than an inch above the first one. The part of the vein between the two ligatures having been left filled with blood, a thrombus was thus obtained. The specimen was removed on the ninth day. In this case the clot was found to have simply mechanically distended the tunics of the vessel, making the study of the conditions presented by the tunics more easy, but not modifying the character of the reparative process. It was an unirritating injection-mass that was awaiting to be invaded and appropriated by active cells from the adjacent tissue.

The reparative changes which had been provoked by the application of the ligature may be regarded as having had, as their first object, the restoration of function in parts whose nutrition had been disturbed by the original application of the ligature. But the agent which had disturbed the nutrition of the tunica interna, and provoked a more active metamorphosis and proliferation of its cell-elements, had at the same time held the vein-walls in coaptation until the confluent plastic material formed had become sufficient in amount and tenacity to permanently unite them together. Essentially the process is that of the formation of a cicatrix, and in its course the ligature plays the same part as does the suture in ordinary wounds—that of maintaining coaptation until firm adhesion is secured. There may be seen in this, also, the same process as that by which a simple longitudinal slit in a vein-wall may be repaired without obstruction to the current of blood through the vessel, the edges of the slit themselves furnishing the material for its repair, the amount of which material, if only further irritation or traumatism be withheld, being strictly limited to the reparative needs of the injured structures.

The two following cases, from Lidell,[1] may be quoted as involuntary experimental demonstrations on the human subject of the repair of vein

[1] Injuries of Blood-vessels. International Encyclopædia of Surgery, iii., 115 and 197.

wounds, when undisturbed. The first case occurred in the practice of Professor S. D. Gross:

Case I.—A strumous lad, aged 14, was wounded in the neck by an accidental discharge of a fowling-piece, loaded with large-sized squirrel-shot, which entered the neck at four or five different points. The casualty was attended with but little hæmorrhage, and the symptoms of shock soon passed away. The wounds healed without any application, and everything went well until thirteen days after the accident, when the patient was seized, suddenly and without warning, by a protracted epileptic convulsion, affecting chiefly the left side, and died the following day, without return of consciousness. *Autopsy.*—One shot had perforated the subclavian artery, and had lodged in the first rib. The calibre of the vessel was unimpaired, and the apertures were closed by small clots extending around the exterior of the vessel, upon the removal of which the margins of the wounds appeared as if they had just been inflicted. The artery presented no marks of inflammation.

Another shot had perforated the anterior wall of the right internal jugular vein, and had lodged on the inner surface of the opposite wall, where it had become completely encysted. The vein bore no evidence of inflammation. The opening in the anterior wall was perfectly closed, and there was no external nor internal clot. The lumen of the vein, however, was somewhat diminished by the projecting cyst.

Case II.—Professor Langenbeck, while removing an epithelial cancer, wounded the internal jugular vein, and tied the cardiac end only, there being no hæmorrhage from the distal end. The common carotid artery, being involved in the tumor, was tied with two threads and divided. When operated on, the man had bronchitis, from which he died on the twelfth day. A *necroscopy* showed the vein completely healed, as if by the first intention, without the slighest trace of redness, thickening of its walls, or formation of a clot.

LATERAL LIGATION.

The considerations which have been described, as to the process of repair after ligation of veins with unirritating ligatures, find an important practical application in determining the propriety of substituting a lateral ligature, or a lateral suture, for ligatures encircling the entire vessel in the treatment of wounds involving but a portion of the wall of a great vein.

The use of lateral ligatures has been strongly condemned by many

surgical writers. Malgaigne [1] says, "the lateral ligature will be an operation always to be condemned," and that "for very extensive wounds of venous trunks, where compression is insufficient, the only resource is the ordinary ligature." The objection of this author was founded on the erroneous belief that permanent hæmostasis after a vein-wound depended upon the formation of a clot sufficient to occlude the entire lumen of the wounded vessel. Inasmuch, therefore, as the lateral ligature in some cases might fail to provoke the formation of such a clot when the ligature should come away, in such cases secondary hæmorrhage would be inevitable. The objection of all surgeons who have rejected this measure as a justifiable proceeding, has arisen from the frequency with which secondary hæmorrhage has occurred in the cases in which it has been employed.

Braun [2] has compiled from published records twenty-four cases in which a lateral ligature was applied, and three cases of lateral forcipressure. Of these nine died from pyæmia and from secondary hæmorrhage. In one case the ligature slipped, and the hæmorrhage had to be controlled by other means. In thirteen of these cases, the internal jugular vein was the vessel wounded. Lateral ligature was applied in twelve instances, and forcipressure in one. Three deaths resulted from secondary hæmorrhage. In seven instances the femoral vein was involved. Lateral ligature was applied in five cases, and forcipressure in two. There was one death from secondary hæmorrhage, caused by the slipping off of the ligature, and five deaths from pyæmia. Five cases in which the axillary vein, one in which the subclavian, and one in which the external jugular were involved, all recovered.

The deaths from pyæmia were all due to septic hospital influences, and are not to be attributed in any way to the special method of ligation adopted. The proportion of cases of secondary hæmorrhage, however, is so great that, unless the danger of such a complication can be shown to be avoidable, the practice must be condemned, since its dangers outweigh any advantages that might otherwise attach to it.

These disasters, however, have occurred in connection with the use of ordinary ligatures, the dangers of which, even for use in ligations of the whole circumference of a vein, have been dwelt upon, and such use deprecated. Much more imminent is the danger which their use entails when

---

[1] *Médecine Operatoire*, ed. 1861, p. 114.

[2] *Ueber den seitlichen Verschluss von Venenwunden. Archiv für klinische chirurgie*, 1882, xxviii., 654-672.

applied to the side of a vein. In many cases, as Malgaigne feared, no clot would have formed to act as a plug to the hole in the vein produced by the separation of the slough grasped in the loop of the ligature, nor would a sufficient amount of plastic exudate have gathered on the interior of the pucker, at the site of the ligature, to substitute a wall of new tissue for that carried away by the slough. Secondary hæmorrhage, in such cases, is inevitable. Lateral ligation, therefore, should not be employed when the surgeon must make use of an ordinary thread for his ligature. In such cases the entire vessel must be included in the ligature, which must be applied both above and below the wound, and complete division of the vessel between the ligatures be done.

The use of aseptic materials for ligatures, which may be cut short, and over which speedy union of the entire wound by first intention may, with much certainty, be secured, places the subject of lateral ligature upon an entirely different basis. Care is first necessary that the ligature is securely applied, lest the accident of its slipping off should expose to disaster. Then the rent in the wall is virtually transformed into an extravascular injury, and the tissues of the puckered wall of the vein, in the grasp of the ligature, are placed in the same condition as that which characterizes veins when ligated in their whole circumference. No thrombus is required, nor formed, by its insufficiency or its disintegration, to become a source of danger. There is no ulcerative process to extend unduly, and to leave an opening in the vein-wall when the ligature comes away. That the process of the exudation and complete organization of the plastic material that fills in and effaces the irregularity produced by the application of the ligature should proceed undisturbed to its conclusion, demands, simply, that the general precautions for securing wound-repair be observed. The ligature acts as an unirritating reinforcement that prevents the rupture of this new tissue during the yielding period of its history, and itself is finally disintegrated, and is removed in the course of the ordinary tissue changes of the part.

Practised with aseptic materials—catgut or silk—with antiseptic precautions, lateral ligature is a safe and valuable means of treatment in wounds of the lateral walls of veins. It should especially be employed in the case of wounds of the main veins at the roots of the extremities, as the axillary, subclavian, and femoral, the complete closure of which would be likely to seriously disorder the circulation of the limb of whose blood it is the channel of return to the heart.

LATERAL SUTURE.

The application of a suture suggests itself as a resource in lateral wounds of large veins, when such wounds are too long or extensive to admit of being closed by a lateral ligature. Cheyne relates [1] the following case, in which this procedure was adopted by Mr. Lister: In removing some cancerous glands from the axilla, a small vein was torn away from the axillary vein at their junction, making, practically, a longitudinal rent in the axillary vein. Taking a fine curved needle and the finest catgut, he stitched up the rent by the glover's suture. The patient recovered without the slightest bad symptom.

Braun (op. citat.) relates that Czerny performed this operation upon the internal jugular vein, but hæmorrhage recurred so that acupressure became necessary. Schede was more fortunate. He stitched the femoral vein with a fine needle and the finest of catgut. He then sutured also the sheath of the vessel. Union by first intention followed.

The same considerations are applicable to the lateral suture which have been elaborated in connection with the lateral ligature. When it is performed, the edges of the wound in the vein should be brought out so that, as the thread is drawn up, the internal surfaces of the divided vein flaps shall be brought in contact. Upon a large vein like the internal jugular, it might be found practicable to hold the wound-edges together by a "through-and-through" continuous stitch, instead of by the ordinary "over-and-over" glover's stitch. This would bring the surfaces of the intima into more certain and extensive contact, and therefore would be preferable. Silk—aseptic—is to be chosen for the suture material on account of the greater ease and certainty with which it may be manipulated. A very fine strand is to be used. The ordinary round sewing needle of the sempstress should be employed for introducing the suture, since the puncture which it makes will be more perfectly filled by the thread that is drawn after it than when a needle with cutting edges is used.

---

[1] Antiseptic Surgery, 76.

PART II.

SPECIAL WOUNDS.

SECTION III.

WOUNDS OF SPECIAL REGIONS.

CHAPTER XVIII.

WOUNDS OF THE HEAD.

Anatomical Considerations—Superficial Wounds of Scalp—Bruises and Contusions—Punctured and Incised Wounds—Extensive Lacerations—Superficial Gunshot Wounds—*Deep Wounds of Scalp with Injuries to the Cranium*—Signs of Compression of Brain Absent—Fractures of the Skull—Indications for Trephining—Fractures of the Base of the Skull—*Compression of the Brain*—Wounds of Intracranial Vessels and Sinuses—Injuries to Cranial Nerves—Wounds of Brain Substance—Hernia Cerebri—Wounds during Birth—Bandaging the Head—*Trephining*—Indications for the Operation—Operative Technique—Excision of Irregular Fragments—*Wounds of Eye*—*Wounds of Internal Ear*—*Wounds of the Face*—*Wounds of the Mouth.*

ANATOMICAL CONSIDERATIONS.

There are many points in the anatomy of the skull which are of paramount importance in considering the nature and occurrence of wounds of its component bony parts and of injuries to the substance of the brain ; but those especially concerning us when considering the treatment of these lesions are comparatively few, and can be covered in a few words. The periosteum of the cranium—usually called the pericranium—is thin but quite strong and resistant. Except over the sutures and at the great foramina it can be easily stripped off, or even made to glide over the bone. In old people its connection with the bone is more firm. It is nourished principally by vessels from the bone. Concerning the bones themselves it should be remembered that the diploë is wanting both in young as in advanced life.

Of great importance are the connections which the veins of the superficial soft parts enjoy with the sinuses of the bony cavity and the veins of the diploë through the emissoria Santorini. The most important of these anastomoses are : 1. Among the occipital veins, which connect through the mastoid foramen with the lateral sinus. 2. Along and around the inter-

parietal suture, especially its posterior extremity, where numerous openings connect with the superior longitudinal sinus. 3. The ophthalmic veins, according to Sesemann's investigations, empty as well into the cavernous sinus as into the facial veins. By this it will be seen that the sinuses of the brain have their overflow outlets, or "waste weirs," in what would seem to be abundance. On the other hand, this freedom of venous connection enhances the danger from pyæmic or thrombotic trouble in cases of erysipelas or phlegmon of the external soft parts.

SUPERFICIAL WOUNDS OF THE SCALP.

It will be well at the very outset of our consideration of this subject to give the greatest possible prominence to the classical dictum, "No injury of the head is too slight to be despised, nor too severe to be despaired of;" a statement only strengthened by time and experience. The temptation is very great to ignore trivial wounds, to insufficiently cleanse them, to carelessly dress them. If nothing else teaches the danger of carelessness in these cases the experience gathered from the sword duels of German students should be convincing, since each year several deaths are caused by apparently trivial or commonplace wounds.

We may divide injuries to the scalp and adjoining soft parts into bruises and contusions, penetrating or incised wounds, and extensive lacerations, and discuss their treatment accordingly.

Bruises and Contusions.—A mild bruise or contusion, which may have caused some abrasion, but no other solution of continuity nor any harm to bone, may be dressed with ordinary evaporating lotions, or cold applications either in bladders or ice-bags, or by compresses frequently wet in cold water. If there be any superficial abrasion some antiseptic should be used, a little alcohol or some tincture (*e.g.*, tr. arnica or spts. camph.), or carbolic acid or iodoform. Any ordinary effusion of blood between scalp and bone will be checked and then rapidly reabsorbed under this treatment. The hair may be cut short, or shaved if occasion require. If effusion be very great, and apparently not checked after prolonged trial with simpler measures, then it may be well by free incision to turn out the more or less fluid blood, search for bleeding vessels, twist or tie them with catgut, cleanse thoroughly, wait until all bleeding has stopped, and then neatly approximate the edges of the wound with fine silk or catgut, with the insertion of a few threads of horse-hair for drainage, and over all a firm

compress. Of course all this should be done with antiseptic precautions, meaning thereby irrigation with carbolized water, clean instruments and sponges, and dressing with some absorbent antiseptic material (Chapter X.). Rest and avoidance of exposure must then be enjoined.

Punctured or Incised Wounds.—A small punctured wound, as made by some sharp instrument, should be treated by careful cleansing and then by antiseptic occlusion, as with borated, salicylated, or iodoform cotton. A small knife-blade, the point of a foil, or other pointed instrument may pierce the soft parts over the course of some vessel, and without doing material injury to the bone sever or wound an artery or vein. Several cases of aneurism of terminal vessels have been reported as occurring in this way. From such a wound hæmorrhage would be free, while it would be easy to recognize whether an artery or vein, or both, had been injured. If a vein, pressure will in most cases be sufficient; this pressure should be made a part of the antiseptic occlusion, being maintained by an elastic bandage or some mechanical device, as by including in the bandage a piece of compressed sponge which shall later be moistened with carbolized water.

But if an artery be wounded and such pressure be insufficient, the next measure should be the introduction of a needle threaded with silk, which should be passed, close to the wound, under the vessel and then out; the thread can then be tied in a simple knot or over a compress tight enough to constrict the same. A hare-lip pin or even a common pin may be used instead, a thread being tightly twisted over it in a figure of eight. If this measure be required it should be done on either side the cut, which should be then cleaned and occluded as before. Or, if required, the wound may be freely extended with a scalpel, the hair having been removed, and then the bleeding vessel caught and secured. After this careful cleansing, approximation and occlusion as before.

Extensive Lacerations.—Extensive lacerated or complicated incised wounds are often inflicted, by accident or through homicidal intent, which may even strip the pericranium off the bone, yet without causing any more dangerous symptoms than a temporary concussion or "stunning." In these cases, after having satisfied himself that no fracture of the bone has occurred, at least none calling for operative procedure, the surgeon should first attend to every oozing point or spurting vessel, and clip short the hair about the region of the wound. He should then, with sponge and forceps, address himself to the removal of every particle of dirt and every

loose hair. Any shred of tissue about whose vitality there is the least doubt had better be clipped off. All bleeding being checked it remains now to close the wound; but one cannot be too careful to convince himself that every speck of dust is removed. If now the pericranium have been stripped up, its edges may be approximated with fine catgut. Or if its edges closely correspond with those of the scalp, they may all be included in one stitching. It is well to omit a stitch at each angle or end of the wounds to allow for escape of pus, should any form; though if all these precautions have been observed one may expect union *per primam intentionem.*

Rather fine silk is perhaps the best material for these sutures; it may either be carbolized or prepared with a carbolized wax, which makes it stronger. Stitches should not be more than a quarter-inch apart, and may be either continuous or interrupted, according to the fancy of the surgeon; excellent results may be achieved with either. If drainage seem to be indicated, it may be accomplished by a few horse-hairs, or a bundle of two or three silk or catgut threads, laid especially in those angles of the wound which are to be dependent. It has been suggested to use the natural hairs of the part for the approximation of the lips of an incised wound of the scalp; but it is difficult to make a knot tied with hair hold firmly enough to answer the purpose. Still, it may be tried in trivial cases; in more severe ones it is hardly to be adopted.

The wound being neatly closed, an excellent dressing is the following: A narrow strip of protective, moistened with a solution of corrosive sublimate, 1 to 500, is first laid over the wound; then a few layers of gauze, preferably naphthalin gauze (for reasons elsewhere stated, *vide* p. 305); then a layer of borated or salicylated cotton to give elasticity to the compress; then a few larger pieces of gauze, a piece of macintosh, gutta-percha paper or waxed paper, and over all a roller bandage so applied as to make adequate pressure. The writer prefers the protective slip applied immediately over the line of the wound, because it does not permit dressings to dry and stick to the wound or to the ends of stitches, and thus permits change of dressings without discomfort to the patient.

This dressing need not be changed for from two to six days; earlier, if provision have been made for drainage; later, if not. If thought best an ice-bag may be applied outside of its mass.

In those cases which occasionally occur where some part, or nearly the whole, of the scalp has been torn of, or loose, as by machinery or "scalp-

ing," if the patient be seen in time, an effort should be made to replace the loose portion. Some astonishing successes in these cases have been reported, and at least no harm is done if the trial fail. The general rules already given are sufficient to guide the reparative effort; accurate approximation and judicious pressure being the important canons of treatment along with careful antisepsis. Should the effort partially succeed or fail, if the loss of substance be small, a plastic operation may be attempted; otherwise the bare or raw surface must be kept clean, healthy granulations stimulated by some such application as amorphous boracic acid, and, when attained, the healing process still further assisted by skin grafting, or the newer "sponge grafting." The sponge may be applied in fine flecks, or in larger but very thin slices. No case of this kind which is not speedily and primarily fatal need be despaired of.

The possibility of occurrence of erysipelas in all these cases should be borne in mind, and for that reason additional attention should be paid to enforcing perfect rest, and this by sedatives, when necessary, as during an attack of delirium tremens, and to securing a soluble condition of the bowels, combating fever, keeping up the strength, etc. Any reasonable medicinal means for attaining any or all of these conditions are justifiable. Moreover, the use of naphthalin, in gauze or in fine powder, as a local antiseptic, is recommended, especially because of the peculiar properties which it seems to possess as opposed to, or preventing, erysipelas.

It may happen that we have a case to deal with which has already become inflamed, or perhaps erysipelatous, either through bad attention or lack of any. We should then proceed as follows: The region of the wound should be carefully shaved, or the hair clipped short as possible. If the appearance of the part, or the general condition of the patient, indicate any septic process, the wound should be opened, and its interior freely exposed to view, while a most painstaking disinfection of its entire surface should be made. Suppurating or foul spots or surfaces may be treated with an eight per cent. solution of zinc chloride, or with strong carbolic acid, new openings made for drainage in most dependent parts, and, according to circumstances, the edges reunited, the whole left more or less open and drained, or putrefying and necrosed tissue removed with knife, scissors, or curette. Instead of the zinc chloride, or after it, an ethereal solution of iodoform or naphthalin may be used. Abscesses should be freely laid open, and their cavities scraped out if necessary. If erysipelas have supervened, the whole scalp may be covered with antiseptic

poultices; it may be kept well smeared with a fifteen to twenty per cent. ointment of naphthalin, or the old-fashioned treatment of white-lead paint, rubbed up with a little turpentine, may be resorted to. (It will be remembered that turpentine is a very fair antiseptic.) Few surgeons would feel justified in making ice applications to an erysipelatous scalp, unless cerebral complications were extremely severe. Of course, when we bear in mind the anatomical connection of the scalp and deeper parts (*vide* first paragraph of this chapter), it will be understood that all attacks of erysipelas about the scalp are at least serious.

When called to treat the later results of former injuries in the line of granulating or sluggish ulcers, or exposed and carious or necrotic bone, there are no indications in their case calling for different treatment than similar conditions elsewhere on the body. A healthy ulcer may be covered by skin or sponge grafts, or by a plastic operation; an unhealthy one should be first rendered healthy, and this best, perhaps, by aid of boracic acid and an occasional stimulating with caustic. All dead or dying bone should be removed with curette or chisel, and the surface then allowed to heal by granulation, or covered by a plastic operation, or both.

Superficial Gun-shot Wounds should be treated on the general principles above enunciated; but it must be remembered that a bullet may not only pursue a devious and tortuous path, but may carry in foreign matter. Such a wound should either receive primary antiseptic occlusion (p. 248), or its track be carefully cleansed and drained, being laid open for this purpose if necessary; after thorough disinfection it does not differ from any other wound of the scalp, so far as indications are concerned. Bullets may be left until a subsequent convenient time for their extraction, or they may be searched out at once and removed, with due antiseptic precautions.

DEEP WOUNDS OF SCALP, WITH INJURIES TO THE CRANIUM.

Those in which there are no Signs of Compression.—The first procedures in these cases are not different from those already mentioned. An antiseptic cleansing of external surfaces, and a removal of hair in the neighborhood of the lesion, are first to be effected. Next should follow a checking of all hæmorrhage, as before described. Then a careful examination of the wound should be made. Should it appear that a small external wound conceals more extensive injury or laceration beneath, then free incision should be made in order to expose every part to sight or touch.

According to the extent of these deeper lesions should the superficial wound, as now extended, be reunited or not.

It may happen that one or more pieces of the external table may be entirely separated from their bony surroundings, and held only by their connections with the periosteum and soft parts. Not forgetting that they may be still nourished by these connections, it is, on the whole, the safest plan to remove them. But should a prominent process of bone be thus detached from its seat—as, for instance, a part of the supra-orbital ridge, or margin of the orbit, or even the mastoid process[1]—it would only be good practice to make every endeavor to save it. Such a fragment may be held in place possibly by pressure, by stitching together edges of periosteum, or by drilling and inserting catgut sutures. But pieces of bone that lie entirely loose must be unhesitatingly removed, even if the dura mater or brain be thereby exposed.

Should hæmorrhage from a denuded external surface of bone, or oozing from the deeper portion occur and delay the surgeon, it may be checked by irrigation or sponging either with ice-water or water as hot as can be borne; preferably the latter. After it has been once fully checked it is not likely to recur after the parts are closed in from the air, as when the dressing with suitable compression has been made.

Aside from leaden projectiles a variety of foreign bodies may not only injure the cranial bones, but parts of them may even be embedded; workmen's pointed tools, knife-blades, bayonets, sword or foil points, arrow-heads, hatchet or tomahawk points, pieces of glass, etc. In proportion as these penetrate deeper, the gravity of the wound and the possibility of depression or perforation of the inner table are greater; but the indications do not differ greatly so far as the therapeutic measures are concerned. Obviously their removal is called for, in most cases at least, and this should be accomplished with the least possible disturbance. If a simple pull be insufficient, enlargement of the external wound and instrumental aid must be resorted to. Strong forceps, a pointed elevatorium, a removal of surrounding bone by means of chisel or gouge, and possibly even the trephine, may in succession be called for. The more recent the case the better, as a rule, the results. If any pointed instrument should evidently have penetrated the cranium, it should be removed by the most direct pull in the direction of the line of its entrance, so that farther injury to brain tissue

[1] *Boullet*, Thèse de Paris, 1878. *Dupuytren*, Leçons orales, t. i., p. 58. *Bergmann*, Kopfverletzungen, p. 252.

or coverings may be avoided. As more or less hæmorrhage may take place from the wound in the tables of the skull immediately after removal of the body, especially if it have penetrated, absorbent cotton should be plugged into the wound, or the head at least placed in such a position that bleeding into the cavity of the cranium may not take place.

In every case where solution of continuity of the outer table has occurred, the surgeon should bear in mind what a vantage ground the diploë offers for the lodgement of septic germs and for the development of inflammatory and septic thrombotic processes which may greatly militate against the safety of the patient; and he should in such cases omit no precaution which may tend to avert their destructive agency. Rigid antisepsis, or preferably, if it can be put into practice, rigid *asepsis* must be the motto; without it no such wound can be properly treated. To quote Bergmann (l. c., p. 83). "We have learned to appreciate that every wound, every contusion of the head fares better in the poorest private dwelling than in the richest hospital. And if this protection [antisepsis] is indicated in private practice, it certainly does not come amiss in the worst hospital."

If instead of finding some portion of bone chipped off, or some foreign body embedded or loose, we find simply lines of cleavage indicating linear fracture, different lines of treatment should be pursued, according to what we judge the character and extent of the fracture to be. If symptoms of compression indicate protrusion inward of some bony fragment of the inner table, the trephine is called for, as will be subsequently considered when discussing the indications for trephining. If, on the other hand, no sign of intra-cranial trouble be manifest, and no loose piece of bone demand removal, the case should be treated much as if no such serious lesion were present, save that the antisepsis should be rigid, and absolute and prolonged rest be insisted upon.

It will be as appropriate here as anywhere to discuss the treatment of any severe contusion of the skull, which from the history of the injury or the inherent features of the case has in all probability produced some fracture of the cranial vault. Such a fracture is to be considered from the same point of view as a simple fracture of any bone, deriving special importance only when there is concomitant or subsequent injury to the cranial contents. Notwithstanding the internal table is often very extensively injured, many cases of simple depressed fracture proceed to permanent recovery without any active treatment and without alarming head-

symptoms at any time in their course. In all cases of simple fracture, whatever the depression, or however great the comminution of the bone, a conservative line of treatment should be adopted, and the simple fracture converted into a compound one by incision of the soft parts covering it, for the purpose of the application of a trephine or the removal of detached splinters of bone, only when prolonged or alarming symptoms of intracranial mischief render it imperative. As to the conditions in which immediate resort to the trephine, in cases of simple fracture, is imperative, in the opinion of Sands, of New York, there are but two, of which he speaks as follows:[1]

"One of these is the case in which the fracture is of limited extent, and in which there is reason to think, from its situation, or from the occurrence of monoplegia, monospasm, or hemiplegia, that a splinter from the inner table may have penetrated the motor tract of the cerebral cortex. But, as we have seen, the fractures which are attended with such displacement of fragments of the inner table are usually of small extent, and are almost invariably compound. The other case is the one in which compression of the brain is caused by an accumulation of blood between the dura mater and the cranium. Such an accumulation may result from a wound of one of the larger venous sinuses, but in a large majority of instances it depends on a wound or a laceration of the middle meningeal artery. The accident is most frequently accompanied by a compound fracture; but it may be met with in cases of simple fracture, and occasionally when no fracture is present. When there exists a compound fracture, the blood usually escapes through the external wound, thus rendering the diagnosis easy; but when the fracture is simple, or when the artery alone is injured, the extravasated blood separates the dura mater from the cranium, and may be poured out in sufficient quantity to cause fatal compression of the brain. The amount of blood thus extravasated may be as much as half a pint. When the brain has not sustained severe injury, and the symptoms of concussion may be but slight, the signs of the arterial lesion may be quite characteristic. After a blow has been received, usually in the temporo-parietal region, the patient, although perhaps slightly stunned, soon regains consciousness, and exhibits no marked signs of cerebral injury. But after the lapse of a few minutes, or possibly several hours, symptoms of compression appear, and

[1] The Question of Trephining in Injuries of the Head. Annals of Anatomy and Surgery, 1883, viii., p. 99.

soon become very marked, the patient often dying within twenty-four hours from the time of the accident. Hemiplegia sometimes occurs before insensibility is complete; and its detection is important, for the reason that a blow upon one side of the head has been known to cause a rupture of the artery on the opposite side. The accident affords a clear and positive indication for the application of the trephine; yet there are but few recorded cases of the operation."

Should destruction of soft parts be so extreme, should laceration be so extensive, that it seems best to remove more or less tissue, fearing that its vitality is lost, the surgeon need not hesitate to make a plastic operation to cover the defect, provided it seem advisable. And even if the bone have been denuded, nay, even if the dura mater be laid bare, as will happen after certain injuries as well as operative procedures, unless something else contra-indicate it, plastic operations may still be made. The writer has repeatedly succeeded—like every surgeon who has tried it—in making skin flaps adhere, *per primam intentionem*, to portions of the cranial vault whose external table had been removed; while surgical literature contains abundant reference, which coincides with personal experience, to cases in which they have adhered equally well to the dura mater.

In case of a short fissure or circumscribed depression of the *outer* table the surgeon has but little to do beyond careful dressing, and may almost limit his use of instruments to the needle.

Should a sequestrum exist underneath a granulating mass, as may result during the course of some of these cases, it should be removed like a similar foreign mass elsewhere in the body.

Wounds are occasionally inflicted with saws, as in the following case related to the writer. A laborer in a saw-mill fell in such a way that his head was thrown up against a saw in rapid motion. A clean cut was made through scalp, skull, and an uncertain distance into the brain; the line being along to one side of the superior longitudinal sinus. The man was at once removed to his home and medical aid summoned; but there was very little to do and he was treated symptomatically.

Considerable discussion arose as to what extent it would be proper to sew up the external wound, etc., and the home talent finding this too knotty a problem to decide called counsel from a neighboring large city. But while the surgeons were discussing the *pros* and *cons* of this question the patient progressed rapidly, and by the time the matter was finally settled he was evidently out of danger.

Should the reader meet such a case, his best policy would be to abstain from any active interference, to shave the parts, to approximate the edges of the scalp wound, save at certain points for drainage, to use antiseptics and probably ice applications. If any serious hæmorrhage were in progress the case would fall under the head of injuries to the vessels and sinuses of the cranium, to be considered in another paragraph.

The gunshot wounds made by modern projectiles are noted for the numerous splinters around the edge of the lesion they cause. These splinters being loose or almost so, should be carefully removed.

It should not be forgotten that children have no frontal sinus, and that consequently the brain lies close to the front. Hence a fracture of the *os frontis* in children should not be indifferently probed, nor even such an examination made as may sometimes be permitted in an adult, nor need it cause surprise if the dura mater seem very close to the surface.

Fistulous openings may remain long after injuries such as we have been considering have apparently or for the most part healed. Their treatment is the conventional one, *i.e.*, free exploration with removal of all tuberculous débris or diseased bone.

Fractures of the Base of the Skull, and Diastasis of Sutures.—It happens rarely that cases of fracture of the base of the skull which are really amenable to treatment come under the surgeon's care. Too many of these cases are either dead by the time of the surgeon's visit, or are past help and die unconscious. Nevertheless cases which there is every reason to diagnose as fractures of the base do once in a while recover, and it should always be the rule to treat even the most desperate case as if there were at least a possibility that appearances would prove deceptive.

If there be bleeding from the nose it would be well to use a douche of some kind, either quite cold or quite warm water, which should be iodinized. The styptic effect of hot water in epistaxis is as well known as is its power over hæmorrhage elsewhere, and it should be made use of in these cases.

Bleeding or serous oozing from the ear should be treated similarly with quite warm iodinized water, and after the injection the meatus should be filled with boracic acid in amorphous powder, or a little iodoform should be blown in, and then a plug of antiseptic cotton inserted; all this to be repeated as often as may be needed.

Any injury of soft parts or cranial vault that may be discovered should

be treated in accordance with those rules already laid down at sufficient length.

The balance of the treatment must be symptomatic and largely medicinal. If collapse be imminent, local and general stimulation in moderation, not to excess, lest with vigorous reaction come undesirable consequences. If the heart's action be weak, a sponge wrung out of hot water and sopped over the cardiac region, or heat and cold alternated, with hypodermics of ether, or of atropia ($\frac{1}{120}$ to $\frac{1}{60}$ grain). When once the pulse and respiration are satisfactory, and the bowels cleared out, the rest must be left largely to time. Ice applications to the head may be indicated—will be, in fact, if temperature rises or meningitis occur. Artificial nourishment will be required as unconsciousness, paresis, or paralysis complicate the case. This may be administered by the long tube either into the stomach or rectum, as seems best in each case.

TREATMENT OF COMPRESSION OF THE BRAIN.

Treatment of this condition cannot be separated from that of the cause that produces it. Obviously the first measure must be, after cleansing and exploration, the removal of the compressing fragment, if such there be. Next may be considered the advisability of the withdrawal of a certain amount of blood, either by venesection or arteriotomy, for the sake of weakening the heart's action and diminishing the amount of blood in the system. In this connection one should take into consideration the result of Althann's investigations; he found that after bleeding, even though its volume was reduced, the blood could better pass through the capillaries. Nevertheless, remembering, too, that patients often recover quicker from apoplectic attacks after bleeding, we may regard venesection as a proper measure, at least when pressure or congestive symptoms are severe. The return of blood from the head may also be hastened, and its access hindered by having the head well raised, or the patient in an only partially recumbent posture. Saline cathartics are indicated, or any other means which shall tend to drain the blood of its serum, and so compel reabsorption of the effused fluids. Any means also which may persuade the arteries to contract, *i.e.*, vaso-motor stimulants, such as ergot or small doses of atropia, may be useful later. To the same end the constant galvanic current may be employed.

Cold applications are also of undoubted but rather uncertain value in

these cases. Pirogoff has recommended a continual dropping of cold water on the head, or something like a very mild cold douche ; others also have noticed a rapid return to consciousness after this had been tried. The necessary apparatus for this purpose may be easily made with a nasal douche or fountain syringe. When they are at hand the skull-cap of leaden tubes, as made by Leiter, or a coil of rubber tubing supported by a wire frame, through which ice-water shall continually flow, will be found perhaps equally effective.

So much of the operative treatment of these cases as has not already been considered will fall under the head of trephining, to be dealt with further on.

WOUNDS OF INTRA-CRANIAL VESSELS AND SINUSES.

These wounds most often involve the longitudinal and transverse sinuses and the middle meningeal artery. It occasionally happens that these are injured during the operation of trephining, but these are by no means necessarily fatal ; in fact, in more than one case the effect was that of venesection, and was good. If by a small penetrating wound a superficial sinus be punctured, an antiseptic compress may be sufficient to check bleeding ; over this an ice-cold application should be made. The cases are numerous in which rapid recovery has followed this simple measure. Death is in such cases unusual, and results rather from other complications, such as injury to the brain, or partial escape of blood into the cranial cavity, or from septic processes. Genzmer [1] has related a fatal case from Volkmann's clinic of entrance of air into a sinus during extirpation of a sarcoma from the bone and dura mater. But under most conditions this would never happen. Wounds of the cavernous sinus through the orbit have always been fatal.

When a splinter of bone or a foreign body has perforated a sinus wall the blood may escape at once or only after its removal. These cases are rare. The hæmorrhage may be checked by tampons, with ice applications, or the sinus walls may be sewed together, as in the following unique case reported by Professor C. T. Parkes,[2] of Chicago. In June, 1882, he was called to treat a man who had received a compound comminuted fracture of the skull, with depression ; the fracture was just in front

[1] *Verhandl. d. deutschen Gesellschaft f. Chirurgie*, 1877, ii., 32.

[2] Annals of Anatomy and Surgery, 1883, viii., 118.

of the middle of the sagittal suture, extending into and involving the right parietal bone. The depressed portion was fully an inch in longest diameter, and extended a little to right of median line. He had paralysis of left side, but no head symptoms. An anæsthetic having been given, Professor Parkes endeavored to remove the fragments. After removal of two or three a terrific hæmorrhage set in, so that he was compelled to occlude the opening by a pad of antiseptic gauze. Next morning he removed the compress and found the hæmorrhage to at once recur. As rapidly as possible he removed the fragments, exposing the dura mater, when he found a large opening in the upper wall of the longitudinal sinus, from which the blood poured in a stream. He packed the opening with sponge, and, clearing out all débris, smoothed off the roughened edges of bone. Finding the dura entire, with above exception, he removed the sponge and united the edges of the rent with three fine catgut sutures. Bleeding was checked at once, and the man made an excellent recovery. The opening in the sinus was as large as a coffee-bean.

These wounds of sinuses usually heal well, with only a thickening of walls; but entire obliteration of a single channel is of no great import, as Schellmann's researches [1] have shown. The principal danger comes from softening of thrombi.

Holmes,[2] Gamgee, and Gross,[3] along with others, have related cases of penetrating wounds which have injured the middle meningeal artery. It has several times happened that this vessel required ligation during removal of fragments after severe injury; while during our civil war the common carotid was seven times ligated for this same purpose, with three recoveries. When gradually increasing symptoms of compression lead us to fear a rupture of this vessel, although there be no open wound, the propriety of trephining over its course with a view to its ligation may then be discussed. In 1839 Keate removed a depressed piece of bone and caught it in its course while spurting. Tatum, Beck, Hueter, Physick, Bird, Socin, and others have done this or similar operations with success. Should such a measure be decided upon, the coagula should be as far as possible removed, and everything should be done under aseptic precautions. A case of Parker's [4] will be instructive in this connection. In this there was no external wound of soft parts; nevertheless he trephined over the artery

[1] *Ueber Verletzung der Hirnsinus;* Dissertat., Giessen.

[2] Treatise on Surgery, 1875.

[3] Am. Jour. Med. Sci., July, 1873.

[4] Med. Times, 1877, i., p. 91.

on one side, but found no lesion ; he then trephined over the artery on the other side, but found no coagulum outside the dura ; but since the latter had a distended and bluish appearance he incised it and removed a considerable amount of blood. In three days the patient became conscious, and then quickly recovered.

Injuries to the cerebral portion of the internal carotid are much rarer than those to the meningeal. Longmore relates that a bullet penetrated, in one case, through the orbit into the petrous bone and lodged there, but led to erosion of this trunk and fatal hæmorrhage. Some injury of this kind might, if not rapidly fatal, lead to the formation of an arterio-venous aneurism calling for ligation of the common trunk.

The treatment of wounds of vessels in the substance of the brain cannot differ from that already laid down. Could hæmorrhage in the subdural space be diagnosed, it would be good practice to trephine and open the dura. One such case was reported during our war (*vide* Gross, l. c.). "There are 100 cases of hæmorrhage from the middle meningeal artery known. Of these 17 recovered ; in 12 of these 17 the blood escaped through the external wound. Of the remaining 5 one recovered without operation ; the others recovered after trephining and evacuating the blood through the opening. In Hueter's case the bleeding vessel was secured by a ligature" (Sands).

INJURIES TO CRANIAL NERVES.

The treatment of injuries to these nerves inside the cranium cannot be other than symptomatic. Should a depressed fragment or a foreign body press upon a nerve-trunk, removal of the same would meet the principal indication, and, provided the injury were not too severe in other respects, the nerve might regain more or less of its function. When it is certain that a nerve-trunk outside the cranium is severed, it would be good practice to dissect down upon it and unite the severed ends with a fine carbolized catgut suture, just as should be done elsewhere in the body.

WOUNDS OF BRAIN SUBSTANCE.

Inasmuch as these are inevitably complicated with those of parts external, we can draw no abrupt therapeutical distinction. Obviously, if antiseptic measures are indicated for more superficial injuries, they are vitally essential here. We wish to emphasize, also, more fully in this con-

nection, what has already received mention in this work, and that is, the futility—we are almost tempted to say the homicidal effect—of careless or ineffectual probing for bullets, since most of these wounds are made by projectiles. The array of cases set forth by German military surgeons, in which most dangerous wounds, such as when treated by old methods of promiscuous bullet-hunting, were surely fatal, primarily and antiseptically occluded, and never probed nor investigated, have gone on to speedy recovery—this array should be most convincing as to the merits of this practice.[1]

Probing disturbs clots and all reparative effort, and too often introduces septic germs into deep parts. Suppose we know a bullet has entered a head, and are able to follow its track with a probe two inches deep into the brain, what good have we accomplished, what valuable knowledge gained? We knew that it had penetrated; we could have made a guarded if not a very grave prognosis without the probing; we have gained nothing, but, on the contrary, may have introduced new and disturbing elements. The practice, then, which will commend itself is the following:

If, after a gunshot or small perforating wound, there be no symptoms indicating a serious hæmorrhage or compression, as from a depressed fracture calling for operation, the treatment is most simple, and consists of antiseptic cleansing and occlusion of the external wound, cold applications to the head, free evacuation of the bowels, and absolute rest. The occlusion should be made with simple iodoform cotton, or something of the kind. If, after the lapse of hours, symptoms of compression or intracranial lesion supervene, then the trephine will be called for. When once decided on, the earlier it is used the better, and of course with all antiseptic precautions. If, on removal of the disc of bone, it shall appear that depression caused the trouble, after it is relieved no further operation is needed. If a clot be found between dura and skull it should be carefully removed, if necessary by removal of other buttons of bone. If a pouting and dark appearance of the dura make it probable that there is subdural hæmorrhage, an incision through it should be made, and blood removed as before. If, during these manipulations, the foreign body be recognized, it would be well to remove it as gently as possible; but the circumstances must be very rare which shall justify random exploration in the brain for a bullet. Even if a bullet were touched at the depth of an inch, its removal would be attended by risk of hæmorrhage such as might be difficult to master.

[1] *Vide* Annals of Anatomy and Surgery, 1883, vii., 114.

Moreover, many recorded cases prove with what apparent freedom from serious consequences patients may recover with such foreign masses as bullets in their brains. Not a few men are to-day at work, who are known to be carrying some small mass of lead embedded in their brains. The safest rule to follow, then, is to *abstain from all operative measures when the indications become obscure.*

HERNIA CEREBRI.

When from a recent wound, or one of a few days or weeks' standing, protrusion—*hernia cerebri*—takes place, it may seem doubtful whether it would be better to excise the protruding mass or to endeavor to replace it by suitable pressure. Of course the careful surgeon will dress all fresh cases with such a judicious amount of pressure as shall guard against this condition ; but he may be called on to treat it after it has happened. If the hernial mass has commenced to slough, there can be no question ; excision must be practised and hæmorrhage carefully watched for and checked ; twisting or tying any little spouting vessel—pressure, or the not too hot cautery on oozing points, will usually govern this. When the mass appears healthy, gentle but continuous pressure will usually cause the disappearance, within the cranium, of its proper contents. If this cannot be accomplished during the time of an ordinary dressing, compresses and bandages should be arranged so as to exert an unintermitting pressure. After reduction a lead or caoutchouc plate may be adapted to the shape of the part and applied externally as a portion of the bandage technique.

Cauterizing or ligating the protruded mass is almost as dangerous as excising it.

If an abscess underlie it, as may be ascertained by the hypodermic syringe needle when suspected, its contents should of course be evacuated.

Adams has reported a case of irreducible hernia cerebri, in which he succeeded in covering the hernial mass with a flap of skin by a plastic operation,[1] and Kusmin another similar, except that he resorted to skin grafting.[2]

---

[1] Lancet, 1876, No. 11.

[2] St. Petersburg. *Med. Wochschft.*, 1878, No. 17.

WOUNDS DURING BIRTH.

With reference to those injuries to the fœtal head which may happen during natural or artificial delivery, it is necessary to add but little. Even large extravasations of blood are usually absorbed; in extreme cases, after waiting a few days, it might be well to incise them and turn out the clots. Excoriations and bruises made by instruments need only conventional treatment. Fatal phlegmonous inflammation has been known to result from such injury done by forceps, hence the necessity for antisepsis and attention to detail. Symptoms arising from the compression caused by the forceps will usually subside as the head resumes its shape. Should positive fracture take place, it will probably run its course uninfluenced by therapeutic measures. Perfect rest and cool applications will constitute about all that can be done. The prognosis must be based on the amount of injury.

BANDAGES FOR THE HEAD.

Apposition of wound-surfaces, compression, and the retention of dressings in their place require much ingenuity in the application of proper

Fig. 92.—Double-headed Roller.

Fig. 93.—Sagittal Bandage.

bandages in the case of head-injuries. The following figures, copied, together with their descriptions, from Esmarch's "Surgeon's Handbook," will serve to indicate those methods of bandaging most likely to be of service.

The *double-headed roller* (Fig. 92) is applied by placing the centre of the bandage opposite to the seat of injury, and carrying the two heads past

each other with gradually increasing traction upon the wound ; these turns are then brought back again to the starting-point, and the same process repeated several times.

The *sagittal bandage* (Fig. 93), a T-bandage, is especially suitable for transverse wounds of the scalp.

The *halter bandage* (Fig. 94). The first turn begins on the top of the head, crosses the cheek by passing under the chin, and returns to the ver-

FIG. 94.—Halter Bandage.

FIG. 95.—Capelline Bandage.

tex. From here the second turn runs backward round the occiput ; it is then carried from the nape of the neck to the front, round the anterior surface of the chin ; lastly, it returns to the nape of the neck, and ascends again to the vertex. After these have been repeated two or three times,

FIG. 96.—Four-tailed Cap for the Vertex.

FIG. 97.—Four-tailed Cap for the Occiput.

the third turn brings it to a conclusion by forming a circle from forehead to occiput.

The *capelline* (Fig. 95) is a double-headed bandage, the end of which passes round the head from forehead to occiput, and fixes the turns of the

other end, which is carried alternately over the right and left parietal bone, each turn overlapping the preceding one.

The *four-tailed cap* (Figs. 96 and 97) is a rectangular handkerchief, three times as long as broad, and slit at its narrow ends. The figures show the method of its use.

The *head-net* (Figs. 98 and 99) may be made of coarse cotton twine. A narrow linen ribbon, drawn through the meshes of its lower border, will fix it in a circular manner round the forehead, temples, and occiput. A

FIG. 98.—Head-net for Keeping Dressing on a Wound.

FIG. 99.—Head-net Used for Fixing on an Ice-bag.

second ribbon, which is tied beneath the chin, keeps the net down, and a third contracts the net upon the vertex like the string of a purse. It may thus be made to adhere firmly to the surface of the head without exercising too much pressure or causing heat.

TREPHINING.

Indications for the Operation.—As Professor H. B. Sands has remarked in the paper already alluded to, read before the New York Surgical Society: "For ages past no surgical procedure has been the subject of keener controversy, and the diversity of opinion which still prevails concerning it suffices to prove that the question of its value is yet unsettled, and that it is one of inherent difficulty and obscurity." In the opinion of this surgeon, trephining is, however, plainly indicated in all compound fractures of limited extent, accompanied with depression and comminution of the bone, even though not attended with any signs of serious injury to the brain. He says: "Many lives which would other-

wise be lost are saved by the operation, which by elevating depressed fragments, by removing fragments that are loose or sharp, and by permitting thorough antiseptic irrigation of the wound, reduces to a minimum the risk of intracranial inflammation, so greatly to be dreaded in this class of cases. To insure success, however, the operation should be performed soon after the injury, and with strict antiseptic precautions. I recall an instance in which, many years ago, I unfortunately delayed the operation until the third day, in consequence of the entire absence of head symptoms. When these occurred I trephined, but lost the patient, who, I believe, might have been saved by earlier interference. If trephining has not been performed soon after the accident, and the wound seems to be doing well, I should consider it objectionable to disturb it at a later period, unless the operation was indicated by the occurrence of decided symptoms pointing to intracranial mischief. I have seen cases of recovery from compound depressed fractures in which the bone was not elevated; but I do not remember to have met with such an instance, except in children, who, as is well known, bear head injuries much better than is the case with adults.

"While believing that trephining is to be recommended in all cases of compound fracture in which the depression is marked, but of no great superficial extent, and in all cases of punctured fracture, when there is reason to suspect that the internal table is extensively splintered or depressed, I am strongly opposed to active interference when the fracture is of great extent, and when the depression is not limited or abrupt. It is true that these cases are usually fatal; but I am sure that nothing can be gained by the extensive operative procedure that would be involved in any attempt to remedy the displacement. Aside from those cases in which the brain has suffered irreparable damage, I think that in future many successes will be obtained by careful antiseptic treatment of the wound, such as recommended by Lister in the management of compound fracture of the bones of the extremities. The most scrupulous cleansing of the wound, the arrest of hæmorrhage, the removal of foreign bodies, loose fragments of bone, and of detached portions of brain matter, if present, followed by proper drainage and dressings, is, in my judgment, the only means which, with our present knowledge promises any benefit in this nearly desperate class of injuries."

Of those who advocate more free resort to this operation, Professor Briggs, of Nashville, has more recently written.[1] In this paper he calls

[1] Annals of Anatomy and Surgery, 1883, viii., 59.

attention to the frequency, and almost impunity, with which it was done by the ancients and by strolling charlatans in the middle ages. With respect to its adoption he divides surgeons into three classes—(1) those who reject it, (2) those who only practise it when imperatively demanded, and (3) those who recognize it as a valuable prophylactic. The mortality after it is certainly high; but how many of those dying are really killed by the trephine? The well-known case of the Count of Nassau, who was trephined twenty-seven times by Chadbourn, proves the operation, as such, to be no more dangerous than other capital operations. The South Sea Islanders scrape through their skulls with pieces of glass. Among the Cornish miners the operation is, according to Michel,[1] one of daily occurrence. The chief danger in depressed fractures is not the compression, for the brain rapidly adapts itself to that, but the irritation set up by the depressed bone. His motto is, "The early trephine is gold, the late trephine is lead." The risk of converting a simple fracture of the skull into a compound one can by no means equal the positive harm that threatens the integrity of the brain and its meninges if no operative steps are taken. Acting on this plan, that if cerebral irritation clearly point to a local focus the exploratory trephine should be used, he has never had occasion to regret this matter, dreaded by many, of making a compound out of a simple fracture.

Summing up, then, and giving due consideration to the opinion of the older masters in surgery as well as the more recent (Bell, A. Cooper, Brodie, Hewitt, Nélaton, Bergmann), we may make out the list of indications for the trephine about as follows:

Simple fracture, with loss of function from penetration of cerebral cortex by splinter from inner table, or with compression from wound of a meningeal vessel.

Compound fracture, with depression, even without symptoms of compression, except over the frontal sinus in adults.

Punctured fractures, even without symptoms.

Coma, with signs of compression, with bruising of soft parts, but without fracture of the external table.

Hæmorrhage, either to tie a vessel or remove a clot. This is more or less included in the above.

---

[1] Am. Jour. Med. Sci., Oct., 1879.

Other indications not so directly connected with our subject are :

Abscesses of brain.

Epilepsy or mental aberration following a head injury, when the lesion can be localized.

Bone abscess (frontal sinus, mastoid, etc.).

Purulent meningitis ? [1]

In discussing this part of the subject, the term trephining has been used as including not only removal of a disc of bone, but also the use of the bone elevator and Hey's saw. The facts of the fractured area covering a relatively great extent of surface, or the depression not being limited or abrupt, are usually held as counter-indications for operation ; yet here, as everywhere else, the surgeon must be guided by general considerations and by the special features of a given case, and be prepared to use that judgment without which he can in nowise be considered to be a surgeon.

The Operation.—For the operation are needed, besides the ordinary scalpel, forceps, etc., one or more conical trephines, a bone elevator, and a Hey's saw. Sponges, antiseptics, assistants, and the spray being ready, the scalp should first be cleanly shaved. If the patient be unconscious no anæsthetic will be required, at all events at first ; otherwise he should be anæsthetized. An existing wound should be enlarged ; else the bone must be exposed by a crucial, curved, or T-shaped incision ; the pericranium is also raised from that portion where it is intended to perforate. All bleeding vessels should be caught and tied as cut. Hæmorrhage being checked the surgeon plants the trephine on the place selected, the centre-pin protruding, and turning it gently, one way and then the other, sinks the pin-point till the teeth have cut a circular groove. The centre-pin is then withdrawn till it no longer appears on a level with the teeth. The trephine is now worked with gentle motion, withdrawing it frequently to brush the groove in the bone, and its teeth, with the little brush that should always accompany the instrument. Complete division of the outer table and entrance into the diploë will be recognized by the more yielding sensation to the hand guiding the instrument, and the altered, more bloody character of the detritus thrown up by the saw. The surgeon must never forget that children and aged persons have no diploë, their crania being therefore

[1] Gross : Am. Jour. Med. Sci., July, 1873, p. 60. If the gynæcologist can open the peritoneal cavity for acute peritonitis with success, as Tait has done, why cannot the surgeon open the meningeal cavity for the same reason, to let out pus ?—(P.)

so much the thinner. As the instrument is made to cut more deeply it must be the oftener withdrawn and the groove explored with a blunt probe, by which one will be able to distinguish between the bone and the more elastic and yielding dura mater. If the probe go through on one side, he must be very careful to press the trephine only on the other side, and to avoid lacerating the dura with its teeth. Extreme caution is now required. On account of irregularities of the inner surface of the skull it may be impossible to cut everywhere through the whole thickness of bone without endangering the parts beneath. In this case, even at the risk of causing spiculæ of bone, the disc must be broken out.

The trephine having been carried as far as deemed judicious, one end of the elevator is inserted under the disc, and with the margin of the sound bone as a fulcrum it is pried out of place, the elevator point being introduced at several points around its circumference if need be. When loose from bony attachments the elevator and the forceps will facilitate its removal. Sometimes the combined action of two levers may be necessary.

With this removal of a disc of bone the prime object of the operation is attained, and pus or blood may be evacuated, or depressed portions of bone may be raised to their proper level by prying them with the elevator. Before closing the wound all sharp points should be removed and rough edges smoothed off with suitable instruments. If a coagulum is to be extracted it may be broken down with the bent probe and washed away with a stream of tepid carbolized water. It is a favorable sign when the dura rises in proportion as clot is removed.

We have described above the typical operation. In cases of comminuted fracture it may be possible to remove the fragments with the elevator and forceps, without the necessity for making a prior opening. Sometimes a projecting piece of bone may be removed with a Hey's saw without requiring the trephine; this fragment thus removed, an opening is made just as if the trephine had been used.

Certain cautions must be diligently observed.

Place of Applying the Trephine.—It must be rested by its centre-pin upon sound bone. That portion of broken bone, or edge, which is depressed always carries with it a larger portion of the inner table than answers to the diameter of the hole in the outer table. Hence the necessity for observing this rule. Moreover, to trephine the depressed portion might be to depress it still more during the operation.

Points to which the Trephine should never be Applied.—The line of the longitudinal sinus, the occipital bone over the course of the large sinuses, the frontal over the frontal sinus, and the parietal over the course of the middle meningeal artery—at least its lower portion. A point an inch and a quarter, or half, back of the external angle of the orbit marks the site of the artery. If necessity arise for application of the trephine over the frontal sinus, the outer table should be first removed and then the inner.

Should the circumstances of the case, the bulging of the dura mater and its discoloration lead to the supposition that pus or blood be present beneath it, it would then be legitimate to incise it and remove whichever might present.

Whenever removal of one disc proves insufficient for the elevation of bone or removal of clot the surgeon is justified in removing a second and a third even, selecting his points in accordance with the rule above given

The following plates, Figs. 100 and 101, taken from Charles Bell's "Illustrations of the Great Operations of Surgery" (London, 1821), with their commentary and explanation, will serve to illustrate, much better than a long description, some of the practical points in the operation.

After-treatment.—There is little to be said with reference to the after-treatment. Perfect repose, light diet, and sedatives, *pro re nata*, in the way of therapeutics. The wound should be dressed strictly antiseptically, with a few catgut threads for drainage in one or two corners of the wound. A reasonably firm compress must be made over the site of the operation, both to repress any tendency to hernia duræ or hernia cerebri, and to keep the pericranium and scalp in proper apposition with the parts beneath. The scalp-wound, of course, is neatly closed with sutures. But if pus have been evacuated from within the cranium, it will be necessary to make an open wound, and to place the head in the most favorable position possible for drainage.

ENLARGING OPENINGS IN THE CALVARIA.

For the purpose of enlarging openings which already exist in the bones of the cranium for the elevation of depressed fragments, the extraction of splinters of bone or foreign bodies, and to provide for the adequate cleansing and drainage of penetrating wounds of the skull, gouge-forceps may be conveniently used, as in Fig. 102 by means of which the edges may be gnawed away, and the opening quickly enlarged in any direction. Esmarch, in his "Handbook," p. 281, recommends that the sawing out of a

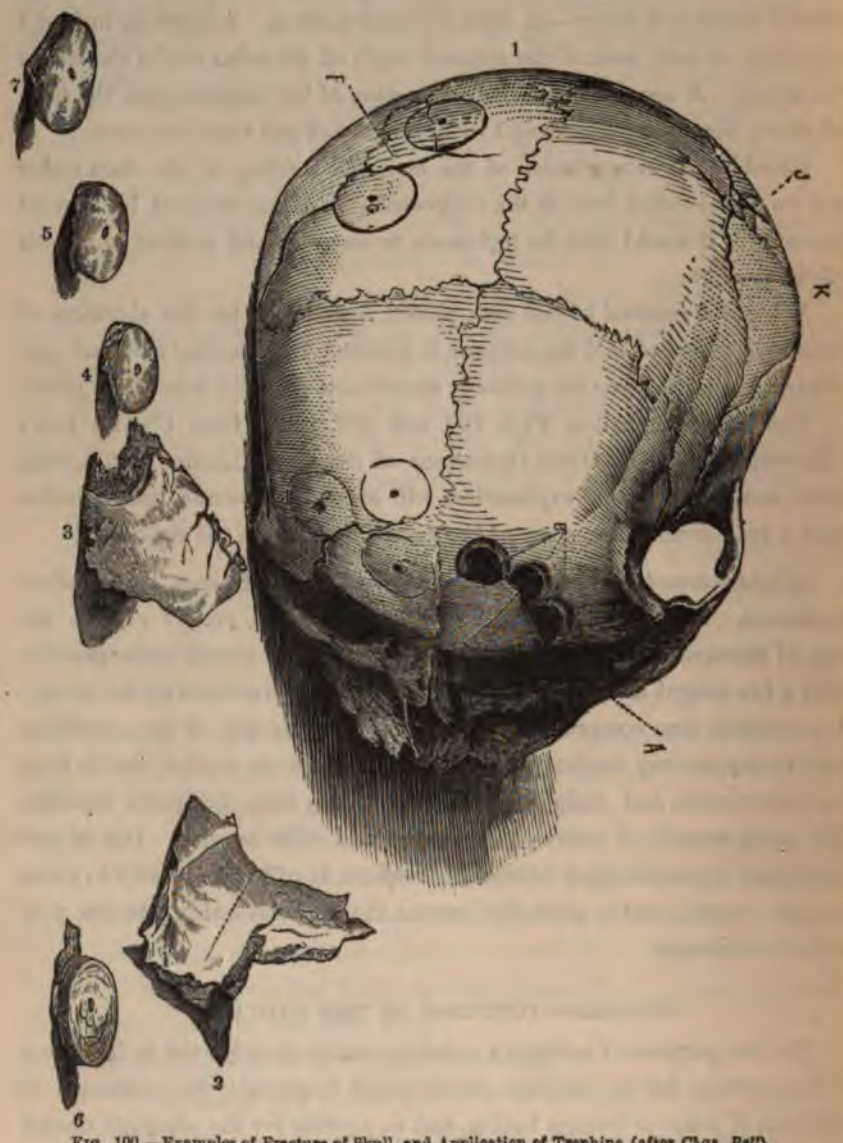


FIG. 100.—Examples of Fracture of Skull, and Application of Trephine (after *Chas. Bell*).

EXPLANATION OF FIG. 100.

1. A skull showing various examples of fracture. A, a triangular portion of the os frontis, fractured and depressed. B, the three perforations found necessary for its elevation and extraction. The edge of the inner table being found to shelve *under* the sound bone made the second and third perforation necessary. This was a mistake, but one which may happen. D, a point where the trephine was employed for a fissure and fracture of the os frontis represented at its right side; a second perforation was made on the sound bone a little higher up, still the bone could not be extracted; the trephine was then applied at E, and the bone lifted up. It should have been applied at E in the first place. F is a fracture with depression at the lower angle. The trephine was placed at G. It ought to have been a large one, and placed at H, by which a portion of bone would have been saved and a more favorable form of opening obtained. By perforating at G an acute angle of bone was left between G and F.

2. Represents the piece of bone removed from A, with its inner table projecting beyond the outer.

4. The button of bone removed in order to elevate the fragment represented in 3. Here, by careless work, the surgeon might have pressed on the depressed portion with the trephine, and thus depressed and chafed the dura.

5 and 7. Buttons of bone having inequalities on their lower surfaces, showing the necessity for extreme caution during the operation.

6. Another button, having considerable inner table attached to it, as occurs when the surgeon is obliged to break up the circular portion.

In 1, instead of the trephine, a Hey's saw might have been used to cut across the base of the fragment at H, but there is always more danger of wounding the dura when using the saw, and it is more difficult to introduce the elevator.

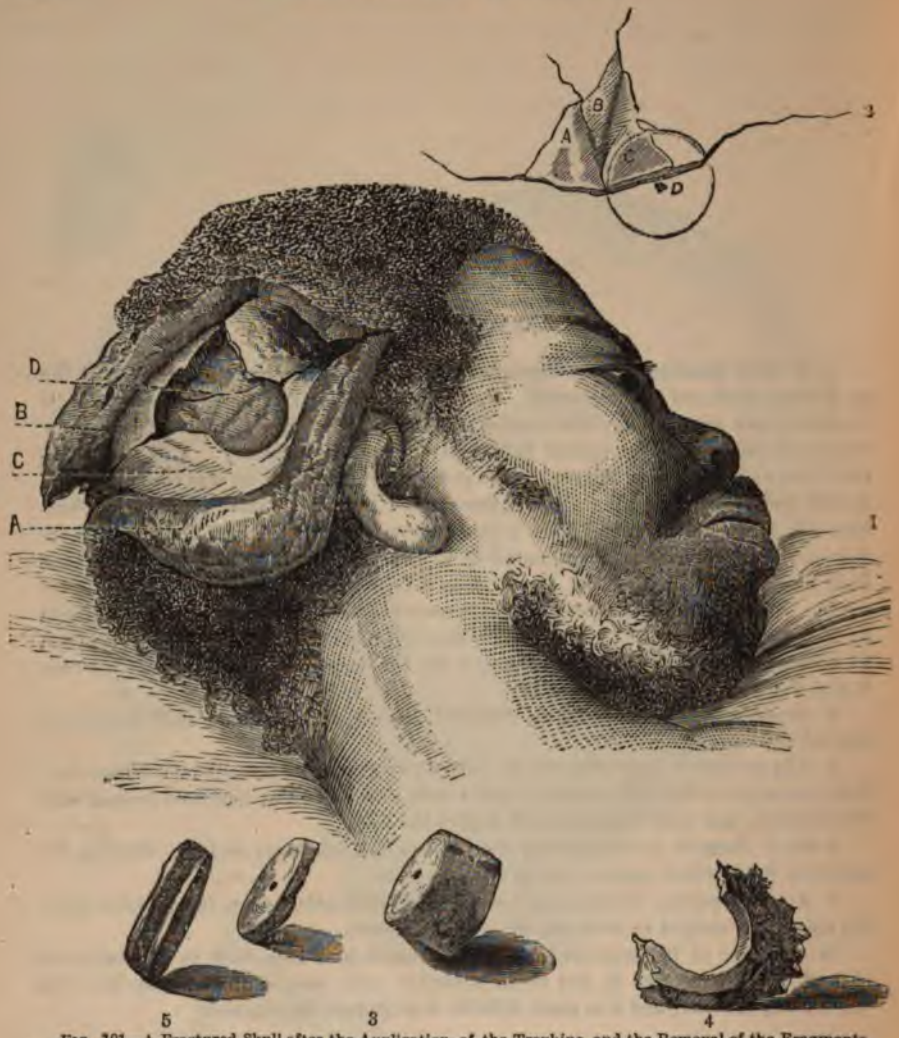


FIG. 101—A Fractured Skull after the Application of the Trephine and the Removal of the Fragments (after *Chas. Bell*).

1. Shows the parts after the application of the trephine and removal of the fragments. A, B, the flaps of integument; C, the cranium; and D, the dura mater exposed.

2. Sketch of the fractured bone. A, B, C, the three portions of fractured bone, with depressed edges, which, being sharp, are irritating the dura; they must, therefore, be removed. They are, moreover, so separated from their attachments as to have lost their vitality. There being no "purchase" for the elevator, the trephine is applied at D, and the broken pieces elevated and picked away.

3. Two discs of bone cut by the trephine, showing the varying thickness of the skull.

4. Exfoliation of bone after use of the trephine.

5. Shows the two tables of the skull, with the diploë between.

circular piece of bone by the trephine be resorted to only in those cases in which there is no opening in the skull. If there is but a narrow fissure which has to be widened, he would use a gouge, a common carpenter's

FIG. 102—Biting off the Edge of Bone, in a Fracture of the Skull, with Gouge-forceps (*Esmarch*).

chisel, and a wooden mallet, with which small, sharp blows should be dealt upon the chisel obliquely placed upon the bone (Fig. 103). When the opening has been sufficiently widened, the gouge-forceps can be used for

FIG. 103.—The Use of the Gouge and Mallet to Enlarge an Opening in the Skull (*Esmarch*).

its further enlarging, as may be necessary. When the object is sufficiently exposed, it is raised by an elevator, grasped with forceps, and carefully extracted.

WOUNDS OF THE FACE, ETC.

Wounds of the eye are usually relegated to the specialist in that department, yet it is essential that every practitioner should at least know what "first help" to render. No careless efforts should be made to remove penetrating particles or bodies, but the eye should be carefully cleansed, a few drops of a 2 to 4 grain solution of atropia be instilled to dilate the pupil and allay pain and irritation, the lid should then be lightly bandaged down, the patient put absolutely at rest, and cold applications made, with, perhaps, the administration of a cathartic. For further information the reader is referred to any of the standard treatises on ophthalmology.

Wounds of the interior of the ear should first be treated with warm water; in fact, warm water is the only fluid that ever should be used in the ear except by direction of the professed aurist. If pain be extreme, though, a few drops of a solution of morphia, with a little atropia in glycerine may be instilled. Beyond this nothing but hot water, made antiseptic, and possibly alkaline, should ever be used.

Incised wounds of the eyelids may be united like other wounds. The approximation should be as neat as possible that the resulting scar may be slight. Fine silk should be used.

A variety of *penetrating wounds of the face* may be met with. Knife-blades and metallic instruments occasionally enter to the depth of an inch or more. If no vessel be severed, repair usually goes on speedily. The less such a wound is disturbed, as by probing, the better. A little wad of antiseptic cotton bound on, or occlusion made by iodoform collodion, over which cold may be applied, will probably be all sufficient. If compression do not check hæmorrhage a hare-lip pin, or curved needle with a figure of eight ligature, or a deep stitch on either side the opening, may be resorted to, both needle and silk having been carbolized. If serious hæmorrhage indicate the division of some arterial trunk, the wound must be enlarged enough to permit application of a ligature to each end of the divided vessel, or possibly a ligature below the wound may be required. Advantage may also be taken of the styptic powers of hot water.

Should fracture of the nasal bones complicate a case, the parts may be supported by tampons of cotton from within the nose, or, better still, according to the method recommended by Mason,[1] they may be supported upon a strong needle passed under them from one side to the other. Should se-

[1] Annals of Anatomy and Surgery, 1881, iii, 107, 197.

vere epistaxis occur, a douche of water as warm as can possibly be tolerated should be given, after which cold may be applied to the back of the head and the hands raised above it.

In any of the great variety of gunshot wounds that may occur, the rule should be as follows: If no serious symptoms indicate a lesion incapable of spontaneous recovery, a simple antiseptic occlusion of the wound will be all that is required; no probe should be introduced. Any symptom of really grave import can be recognized without the probe. Should, on the contrary, the general and particular features of the case indicate some operative measure, it should be, if possible, postponed (of course not too long) till everything is ready—the patient's accommodations, the anæsthetic, instruments, and antiseptic dressings, as well as assistants and nurses. And all probing and investigating should have been omitted until then, when all can be done at one sitting and with better results.

The same will hold good with regard to injuries by larger or foreign bodies, as, *e.g.*, fragments of glass, bombs or shell, or splinters of wood. Primary antiseptic occlusion on the battle-field, or place where injured, and all operative measures later when they can be carefully attended to.

Intractable bleeding sometimes occurs after extraction of teeth, especially in so-called "bleeders." In these cases hot water may serve the purpose, but it will probably be necessary to pack the cavity with some styptic, and then make compression by stuffing that side of the mouth and binding the jaws together.

It may be possible to replace a tooth that has been wrenched or knocked out of its socket, provided the alveolar process be not badly broken, and to fasten it by wire or silk to other teeth or by binding the jaws together.

When fracture of any of the larger bones of the face occurs along with an external wound, making a compound fracture, the general rules governing the treatment of such injuries should be observed;—approximation of fragments, perhaps by wire or chromic catgut, disinfection of the entire wound, provision for drainage, accurate adaptation of superficial wound, and suitable inter-dental or external support.

In wounds cutting through the entire thickness of lip or cheek it should be the effort to coapt the surfaces of mucous membrane as carefully as those of the integument. Otherwise there are no particular indications about wounds of the soft parts of the face or external ear differing from those in other parts of the body. If, however, the surgeon particularly desire to avoid scarring, he may do as Pancoast has suggested with reference

to incisions made during plastic operations about the face—he may take a little more time and *bevel the edges*, so that one shall tend to lap or slide a little way under the other, thus making the cicatrix a mere linear one.

We may add that portions of the cartilaginous part of the external ear which have been entirely removed may be replaced, provided not too long an interval have elapsed, with expectation of reunion in quite a large proportion of cases.

Wounds of the Mouth.[1]—Wounds opening into the buccal cavity, as after extirpation of the tongue, etc., should be lightly packed with iodoform-gauze. The adhesive gauze is here particularly valuable, because by its adhesive properties it attaches itself to the walls of the wound, thereby preventing its being swallowed or causing suffocation, while the iodoform, adhering to the gauze, is not apt to be removed by the secretions of the mucous membrane. The gauze, cut in strips one-half to three-fourths of an inch in width, should be brought into intimate contact with the wound-surfaces, so as to fill all fissures and recesses, and, if necessary, should even be fastened by stitches. In wounds to which the gauze cannot be thus applied, as, for example, those of the throat and palate, the iodoform in powder should be daily insufflated. Drainage is called for only after extirpation of the tongue and other wounds involving the floor of the mouth, in which there is already an external opening. Parenchymatous hæmorrhage is controlled by the gauze. Serum, which at first may ooze through, may be absorbed by sponges fastened on sponge-holders firmly pressed against the dressings.

The gauze, which will form in time a solid mass with the various secretions, should remain *in situ* 8 to 14 days, till it is spontaneously detached.

Secondary hæmorrhage is prevented, and cleansing of the buccal cavity and teeth, formerly carefully attended to, is of less importance.

If the filling of the wound-cavity has been performed with exactness, there will be no reaction, secretions will be at a minimum, the patient will feel well, will experience no pain, and the mouth will be free from unpleasant odor. Only the superficial layers of the gauze will need a renewal, as soon as they are soiled by food, saliva, etc., or if the iodoform in any considerable quantity is washed away, the powdered iodoform should be dusted upon the dressing, more particularly where the gauze has separated from the edges of the wound.

---

[1] Wölfler: *Wundbehandlung im Munde, Archiv für klinische Chirurgie*, xxvii., 419. Hacker: *Anleitung zur antiseptischen Wundbehandlung*, p. 31.

CHAPTER XIX.

WOUNDS OF THE NECK AND OF THE THORAX.

Wounds of the Larynx or Trachea—Punctures—Longitudinal Wounds—Transverse Wounds—Suturing the Trachea—Antisepsis—Tracheal Canula—Intra-tracheal Polypi—Hæmorrhage into Trachea—*Wounds of Pharynx or Œsophagus*—Swallowing Interdicted—Œsophageal Tube—Primary Importance of Deep Union—Longitudinal Wounds—Gunshot Wounds—Transverse Wounds—*Wounds of the Great Vessels of the Neck*—Arteries—Vertebral Arteries—Internal Jugular Vein—Lateral Ligature—Cases of Parkes, Allis, Gerster, Lange, Lidell, and J. E. Pilcher—*Non-penetrating Wounds of the Thorax*—Wounds of Internal Mammary and Intercostal Arteries—*Penetrating Wounds of the Thorax*—Heart and Pericardium—Lungs—Pleuræ—Hæmothorax—Pneumothorax—Emphysema—Empyema and Hydrothorax—Résumé.

WOUNDS OF THE NECK.

The wounds of the neck which present peculiarities that demand special examination are those deep wounds which penetrate the larynx or trachea, the pharynx or œsophagus, or involve the great vessels of the neck.

Wounds of the Larynx or Trachea.—Simple punctures of the air-tube, as in cases of stab-wounds, usually unite by first intention, without introducing any complication in the course of the more superficial wound. Spontaneous apposition of the edges of longitudinal wounds of the trachea may be depended on by reason of the resistance to separation exercised by the cartilaginous rings of its wall. The closure of such a wound by primary adhesion is the rule. Transverse wounds may be made to gape by extending the neck. In such cases the head should be depressed toward the chest sufficiently to bring the sides of the wound in contact, where it should be kept either by the occipito-sternal handkerchief of Mayor (Fig. 104), or by some other apparatus acting on the same principle. Coaptation of the tracheal wound, in transverse wounds, may be assisted, if the case seem to require it, by introducing sutures through the peritracheal fascia, that ensheathes the tube; this peritracheal fascial sheath has sufficient body

to make its suture in such cases a valuable resource in making accurate adjustment and in steadying the wound-edges in their proper relations to each other in those comparatively rare instances in which the trachea or larynx has suffered transverse division through a large part or the whole of its circumference. If catgut is used for such a purpose, it should be cut off short in the wound. If silk, one end should be brought out through the superficial wound, and the suture regarded in the light of an ordinary ligature.

Close approximation of the more superficial wound-surfaces, and their suturing, should not be practised to a degree that would embarrass the free escape of any air, or mucus, or blood, that might be forced out of the

Fig. 104.—Occipito-sternal Handkerchief for Approximating Transverse Wounds of the Neck.

trachea through the wound in its wall by cough or in ordinary expiration. Approximation, with efforts to obtain primary union, should, however, be made of all portions of the wound, with the exception named.

The entrance of sepsis into wounds involving the air-tube cannot be prevented, so that vigilant effort is required to antidote its effects. The free escape of all secretions should receive careful attention that it be perfectly secured. As an antiseptic application the bismuth lotions of Kocher (p. 89), are particularly applicable. By their use, the secondary suture, as practised by that surgeon, may be employed on the second or third day with the result of hastening greatly the period of repair in favorable cases.

In cases in which there is considerable loss of substance of the wall of the larynx or trachea, great care must be exercised to prevent the entrance into the trachea of septic secretions. One of the most frequent and fatal complications of such injuries, as well as of similar injuries of the mouth, is broncho-pneumonia, from the inhalation of septic matters from the wound. For the prevention of such a complication, a suitable canula should be kept in place in the tracheal opening, and the surrounding wound-cavity should be kept packed lightly with adhesive iodoform-gauze, until its cicatrization is well advanced. The use of a similar canula will also be required for purposes of respiration, if that portion of the air-tube above the wound should become stenosed from any cause, as inflammatory œdema, diphtheritic exudate, or cicatricial contraction.

The opening of the canula should be kept covered by a moist and warm sponge to purify and moderate the temperature of the inhaled air, and thus to guard against bronchial irritation from cold or dust-laden air.

Exuberant granulations, forming polypoid excrescences projecting into the trachea, not infrequently form at one angle of a wound in the trachea which has been kept distended by a canula. They are formed by the excessive development of the granulations, which spring up to fill in the angles of the tracheal wound not filled by the canula. Their presence may be a source of dangerous embarrassment to the respiration when the canula is removed. They should be destroyed by the application of caustics, or by avulsion, followed by cauterization of their bases. Whatever operative procedure may be necessary to make them accessible to the required applications should be done. Whenever a prolonged use of a canula is required, watch should be kept for any signs of their development, and their growth repressed from the first.

The escape of blood into the trachea, to the extent even of producing suffocation, is a complication that should not escape the thought of the surgeon in the cares which he gives to the wound. It is to be prevented by thoroughness in the primary hæmostasis, and by the non-closure of the external wound. When blood in any quantity has already been poured into the trachea, it should be removed at once by forcibly compressing the chest while the patient is held with head and neck hanging down, and by the introduction of forceps, armed with sponges, into the trachea through the wound, which may be enlarged, if necessary, to admit of being cleansed. A syringe, if at hand, may also be used to suck out the blood.

Wounds of the Pharynx, or the Œsophagus.—The pharynx, or the œsophagus, may be wounded from within, or from without. In the former case, portions of the ingesta, in the act of eating or drinking, may escape into the connective-tissue of the neck, and produce purulent infiltration of its loose substance. If the wound is in the posterior wall of the tube, the suppurative gatherings may burrow into the posterior mediastinum below. These dangers, and the requirements of "rest" for the wound, make it necessary that the functions of the canal in swallowing food shall be held in abeyance for a time. The patient must fast for the first days, until adhesion of the wound-edges has taken place. He should be sustained by nutritive enemas, which alone may be sufficient to sustain him during the period required. Great thirst may be alleviated by rinsing the mouth with lemon-juice or ice-water, but all attempts at swallowing should be rigorously interdicted. If the rectal alimentation be insufficient or impracticable, a flexible tube should be introduced into the œsophagus to a point beyond the wound and nutritious fluids be supplied to the stomach through this. Such a tube, introduced through the nose, has been left *in situ* for a long time, and the prolonged support of the patient successfully accomplished through it. This physiological rest of the œsophagus should be observed in all wounds of its walls. Cases in which a wound from without has reached and opened the pharynx or the œsophagus, are less liable to be attended by phlegmonous infiltration of the tissues of the neck, or by other septic accidents. The wound in the alimentary canal is, or, in many other cases, may be made accessible to treatment to secure its primary union, and the external wound, by the drainage that it affords, is a safeguard against the retention of irritating matters.

The chief end to which treatment must be directed is to secure, first, union of the wound in the pharyngeal or the œsophageal wall. A simple longitudinal wound, as that inflicted in the operation of œsophagotomy, presents little difficulty. There is no tendency to gaping, coaptation is spontaneous and perfect as long as no attempt at swallowing food is made, the external wound is approximated and treated according to the requirements of incised wounds in general, and primary union results.

Gunshot wounds of this tube do not admit of primary antiseptic occlusion. They should be treated by enlargement of the external wound, and adequate provision for free escape of wound-secretions and débris from the deeper parts of the wound. Drainage tubes should be used, and the wound, after thorough primary disinfection by a carbolic acid lotion,

should be kept lightly stuffed with iodoform gauze and be made to "heal from the bottom."

Transverse incised wounds should be sutured, whenever the wound in the tube is accessible, or can be rendered so by a proper enlargement of the external opening. Aseptic silk thread will make the most convenient material for the suture. The sutures should not include the mucous membrane, but only the submucous and muscular coats. The interrupted form should be used, and the intervals should be small, not exceeding the fourth of an inch. They should be cut off close. The external wound should be cleansed and disinfected, and approximated with a view to secure union by first intention throughout. The head should be kept in a position to relax the wounded structures and prevent gaping.

Wounds of the Great Vessels of the Neck.—*Arteries.*—Should either of the main arterial trunks of the neck be wounded, the rule to expose the wounded vessel and to ligate it above and below the wound is imperative. If large collateral branches be cut, the same rule should be followed, if practicable, and the practicability of the procedure will largely depend upon the anatomical knowledge and the operative dexterity of the surgeon. The following comment on the subject of hæmorrhage and ligations in wounds and injuries of the neck occurring during the War of the Rebellion, is by its surgical historian.[1]

"Grouping the ligations of the large vessels of the neck, performed on account of gunshot wounds of the face or of the neck, we have a total of seventy-five ligations of the common carotid, with a mortality of seventy-eight per cent. . . . Nowhere else, not even in wounds of the forearm or legs, in which the brachial or femoral may have been tied, does the operation of Anel appear to greater disadvantage. Tying the common trunk for injuries of the smaller vessels of the head or neck is an operation based on a fallacious interpretation of the anatomical and physiological relations of the region. Nothing that is not corroborative of Guthrie's admirable suggestions is found in the preceding cases. If the indolent or timid surgeon, who, to control bleeding from minor branches of the carotid, prefers to stuff the wound with styptics, or to perform the easy operation of tying the common trunk, rather than to seek in the difficult anatomy of the maxillary and thyroid regions to place double ligatures at the bleeding point, he may temporize, or may associate his name with the

[1] Otis: Med. and Surg. History of the War of the Rebellion. Part I., vol. ii., Surgical History, p. 423.

necrology of ligations ; but if his patient recover, it will generally be found to be under circumstances in which the surgeon's operative intervention was uncalled for."

Vertebral Arteries.—An exception to the preceding statements is to be made in the case of wounds of the vertebral arteries. The difficulties which surround the treatment of wounds of these vessels are very great. Almost all the recorded cases, and their number is not small, have proved fatal. We quote the following observations from Lidell :[1] "Ligature of the vertebral artery for practical purposes is impossible except in a portion about two and three-eighths inches long, between its origin and its entrance into the transverse foramen of the sixth cervical vertebra. In this part of its course it has been successfully tied by Smyth, of New Orleans, for regurgitating hæmorrhage ; in this part, also, it has been tied, together with the inferior thyroid artery, by Maisonneuve, in order to arrest hæmorrhage attending a shot wound of the neck—with success as far as stopping the hæmorrhage and extracting the ball was concerned, though death occurred from infiltration of pus into the spinal canal, and consequent inflammation. But these successes, complete and partial, afford some encouragement. Having determined by exploring the wound with a finger, or by any other means, that the vertebral artery is punctured in this part of its course, the bleeding point should at once be laid bare, and a ligature should be put round the artery on each side of the aperture. But when the exploration shows that the artery is wounded above the point where it enters the foramen of the transverse process of the sixth cervical vertebra, how can we suppress the bleeding and save the patient? We cannot tie the artery in the wound ; and to tie it in the first part of its course, on Anel's plan, would fail, because the two vertebrals unite to form the basilar artery at the base of the brain, and therefore regurgitating hæmorrhage would occur in the wound whenever the direct hæmorrhage might be stopped in this way. Distal ligature of this artery, between the occipital bone and the atlas, as suggested by Dietrich, would be both difficult in performance and uncertain in result. There remains, then, only the operation of plugging the wounded artery, a measure which has been successfully employed in one case by Dr. Kocher, of Bern.

"On dilating the wound in the neck by suitable incisions, both longitudinal and transverse, and removing the coagula, the blood was seen to come from a point between the transverse processes of two vertebræ, ap-

[1] International Encyclopædia of Surgery, iii., 118.

parently the fifth and sixth. Arterial blood escaped from both the central and peripheral portions of the artery; and the bleeding was arrested by pressure against the transverse processes, either from above or from below. As a ligature could not be applied, a plug of charpie of the size of a pea, soaked in solution of perchloride of iron, was introduced between the transverse processes, and left there as soon as it had been ascertained that the bleeding was suppressed. The external wound, having been closed by sutures, was covered with charpie dipped in carbolized glycerine, Lister's carbolic acid paste was applied, and the dressing was retained in place by a bandage. The head was kept fixed by a stiff collar. The plug in the deep part of the wound was removed on the fourth day after the operation, partly by means of a stream of water, partly by forceps; no bleeding followed. Excepting a slight attack of erysipelas, the patient progressed steadily toward recovery, and was discharged cured a little more than five weeks after the operation.

"But in order to secure the success of this operation of plugging the vertebral artery, it is essential that the bleeding point shall be exposed to view, that the plug shall be placed exactly in the open canal of the vessel, which it must completely fill, and that the patient's head shall be held fixed, and the neck immovable, by a stiff collar."

Internal Jugular Vein.—Wounds of this vessel, when treated by exposure of the vessel and the application of a ligature above and below the wound, result happily in a great majority of cases. The free collateral circulation, through the intracranial venous sinuses, the superficial veins of the head and neck, and the sinuses of the spinal canal, prevent serious discomfort from being experienced by the obliteration of so large a channel as the internal jugular vein, when the character of the wound renders such a proceeding necessary. Lateral wounds of this vessel should be closed by the lateral ligature, if the wound is small; by lateral suture, if the wound is long. The advantages of this procedure are that it may be more quickly done; it demands less extensive dissection and disturbance of the neighboring tissues; it increases the prospects of obtaining union throughout the wound by first intention; and, finally, it preserves intact the function of the vessel.

Of the thirteen cases of lateral closure (12 by ligature and 1 by forci-pressure) of the internal jugular vein included in the statistics of Braun, before referred to (p. 296), there were ten recoveries, in one of which, however, the ligature slipped off and other means were then resorted to.

There were three deaths from secondary hæmorrhage. In addition to these cases, Dr. Parkes of Chicago,[1] has reported three cases of lateral ligation of wounds of the internal jugular vein, followed by recovery in each case. In one of these cases the constriction of the calibre of the vessel caused by the ligature amounted to one-third, and in another to one-half its extent. No untoward symptoms followed in either case.

Dr. Allis, of Philadelphia, reported,[1] also, a case in which he had applied a lateral ligature to the internal jugular vein on account of a wound inflicted in it during the removal of a tumor from beneath the sterno-cleido-mastoid muscle. The recovery was rapid and permanent.

Dr. Gerster, of New York,[2] in a case in which a long longitudinal slit was made in the internal jugular vein, during the removal of a multiple lymphoma of the neck, succeeded in closing the rent by the application laterally of a row of catgut ligatures. Primary union followed the operation.

Dr. Lange, of New York,[3] applied a lateral ligature, of antiseptic silk, to a wound of the internal jugular vein, accidentally inflicted in an attempt to tie the common carotid artery for secondary hæmorrhage. Recovery took place.

Lidell reports[3] another successful case, in which, the internal jugular vein having been punctured while a deep-seated tumor of the neck was being dissected out, the margins of the puncture were drawn together and raised up by a Liston's forceps, and a ligature was tied around them on the side of the vessel.

Dr. J. E. Pilcher's successful case of lateral forcipressure, reported in Chapter XVII. (p. 292), should also be recalled in this connection. These eight recent attempts at securing lateral closure of a wound of the internal jugular vein were all attended with success, and serve to demonstrate the feasibility of the practice.

The chief source of danger, which may threaten the success of an attempt to secure lateral closure of a wound of this vein is the normal lateral pressure of the column of blood in the vessel; whenever the head is elevated, whenever the free entrance of the blood into the thoracic ves-

[1] Proceedings of the Philadelphia County Medical Society, meeting of March 8, 1882, in the Philad. Med. Times, July, 1882.

[2] Proceedings of the New York Surgical Society, meeting of Feb. 27, 1883. Medical News, Phila., 1883, xlii., 278.

[3] International Encyclopædia of Surgery, iii., 199.

sels is impeded, as in coughing or straining at stool, this normal pressure is intensified. The contraction of the muscles of deglutition, and of the muscles which cross it lower in the neck—the platysma, the sterno-cleido-mastoid, and the omo-hyoid—may also affect the freedom with which the current through the vein shall pass.

After any wound of the internal jugular vein, and especially in those instances in which a lateral ligature has been applied, the recumbent position must be maintained until firm union of the wound in the vessel has taken place. All movements of the neck must be restrained by the mass and the stiffness of the external dressings applied to the wound. Immobilization and compression, as far as practicable, should be secured.

The material used for all ligatures of the internal jugular vein should be aseptic, and the treatment of the wound should be scrupulously antiseptic, that, if possible, primary union of the wound may be secured.

Lateral ligature of this vessel should be attempted only when aseptic thread, catgut or silk, is obtainable and the subsequent course of the wound can be kept aseptic. In none of the recorded cases has secondary hæmorrhage or other accident disturbed the course of the healing after lateral ligation when these precautions of antisepsis have been observed. The danger of secondary hæmorrhage should deter from resort to lateral ligation of this vessel when ordinary ligatures are used and the wound cannot be kept from septic contamination. When secondary hæmorrhage occurs, it must be treated by exposure of the vessel and the application of a ligature both above and below the bleeding aperture.

WOUNDS OF THE THORAX.

Wounds of the thorax are subject to the same general divisions as those affecting other parts—they may be incised, punctured, or gunshot, contused or lacerated—and are subject to such variations in treatment as may be appropriate to these varieties. More important, however, in this region is the division into non-penetrating and penetrating wounds. The former class includes those wounds which affect the thoracic wall only, without opening the pleural sac. The latter includes all those which involve injury to the contents of the thorax.

Non-penetrating Wounds.—Superficial wounds of the thorax present no peculiarities requiring special consideration, except the difficulty which attends efforts to secure the advantages of immobility in their treatment,

on account of the continual rising and falling of the chest-walls in respiration. As the result, when union by first intention fails to be secured, the healing by granulation is apt to be retarded in its course. This mobility of the thoracic walls may be restricted by surrounding the thorax with a broad, tightly drawn bandage, which will restrain the movements of the ribs, and make the breathing more abdominal in its character.

Deeper wounds of the thoracic wall may involve fracture of the ribs or costal cartilages, and wounds of the internal mammary and intercostal arteries. The methods detailed in Chapter XV. should be applied to the treatment of wounds complicated by bone injuries.

Wounds of the arteries should be treated, whenever practicable, by their exposure, and the application of a ligature to both the proximal and distal ends of the vessel. The external wound should be enlarged by incision, if necessary, until the bleeding point is brought into view. Certain special points in connection with each of these arteries require mention.

Internal Mammary Artery.—The results of wounds of this vessel have been disastrous in most of the recorded cases. Of the five cases in which it was distinctly recognized, and treatment attempted, during the War of the Rebellion, all terminated fatally. When—as is most frequently the case—the wound which has severed this vessel has also penetrated more deeply and has opened the anterior mediastinum, the cavity of the pericardium or of the pleura, the dangers of intra-thoracic and concealed hæmorrhage are added. According to Tourdes,[1] as quoted by the surgical historian of the War of the Rebellion, more than half the cases are accompanied by section of the costal cartilages, and this section always occurs when the vessel is wounded below the fourth rib by an incised wound. There may be external hæmorrhage, and internal, into the anterior mediastinum, into the pleural cavity and into the pericardium. The diagnosis may be very difficult, for the signs of intra-thoracic extravasation are often equivocal. In continuation, Otis quotes the observations of Nélaton,[2] that if the hæmorrhage is suspended at the time of examination, anatomical considerations may afford presumptive evidence, and that every deep wound near the margin of the sternum, from the first to the seventh rib, should be viewed with suspicion. External arterial hæmorrhage decides the point; but this sign is often absent. The diagnosis may

[1] *Des blessures de l'artère mammaire interne sous le point de vue médico-légal*, Paris, 1849, p. 41.

[2] *Élémens de Pathologie chirurgicale*, t. iii., p. 450.

be complicated by bleeding from wounded lung, and the internal hæmorrhage then affords no decisive sign, the position of the wound alone suggesting the presumption that the internal mammary artery is interested. The vessel is often of sufficient calibre to furnish blood very freely, and death may result either from the profusion of the bleeding or from asphyxia from hæmothorax. If the blood passes into the pericardium, the heart's movement is impeded and soon arrested; if it enters the pleural cavity or mediastinum, there is room for mortal hæmorrhage; and if the patient escape these primary accidents he is exposed to those of putrid decomposition of the extravasated blood.[1]

In all cases, therefore, of deep wounds of that portion of the anterior wall of the thorax, in which the internal mammary artery runs, its external enlargement, sufficiently to permit definite determination of the fact whether this vessel is wounded or not, should be made. The enlargement of the wound should be made by incisions directed slightly obliquely to the axis of the body, from above downward, and from without inward, so that the centre of the incision should be three or four lines external to the margin of the sternum, and in the original wound. All the superficial structures should be freely incised, so as to fully expose the wounded intercostal space. The anatomical difficulties which may embarrass the exposure of the vessel now present themselves. They consist of the shelter which the costal cartilages and the adjacent border of the sternum give to the vessel. In the upper three or four intercostal spaces, sufficient room between the cartilages may be found for the *débridement* needed to expose the vessel; in the lower spaces, resection of a portion of one or more of the cartilages may be needed, and should be promptly and boldly done. The primary and imperative indication is to expose the bleeding vessel, and no superficial structure should be permitted to arrest the effort till its end has been accomplished.

The task is more difficult in cases of secondary hæmorrhage, where the adjacent soft tissues have become swollen and infiltrated, and the vessel lacerated and displaced. The attempt to secure it in the wound, however, should be made; failing in that, the tampon might be resorted to, after the plan of Desault. This consists in placing over the wound a fine compress, four or five inches square. The centre of this is pressed through the wound so as to form a glove-finger-like sac projecting into the thoracic

[1] Medical and Surgical History of the War of the Rebellion, Part I., vol. ii., Surgical History, p. 525.

cavity. This is then stuffed firmly with lint; the angles of the compress on the outside are then brought together, and the intra-thoracic pad or ball of lint is drawn gently outward, and made to compress the wounded vessel against the sternum or ribs. To keep the pad in place, the compress may be tied like a purse, and the ligature secured around a roller or other convenient cylinder. According to Otis, this is the best resource, if the attempt to ligate the vessel fails. The hazard of exciting inflammation in the pleura and lung is less to be dreaded than the danger of hæmothorax. The risks of exciting inflammation of the intra-thoracic parts would be lessened by using antiseptic materials in making this tampon, the outer part being made of antiseptic gauze, and antiseptic cotton, jute, or gauze being used for the stuffing.

Intercostal Artery.—In recent wounds, properly directed attempts to expose the intercostal artery by enlarging the wound should meet with no insurmountable difficulty. As the location of the wound recedes from the sternum, the trouble which may be experienced will be likely to become increased, owing to the greater thickness of the external soft parts, the greater protection exercised by the projecting edge of the rib underneath which it runs, and the larger size of the vessel, and the consequent more profuse bleeding from it. In the later history of a wound, when secondary hæmorrhage from the artery requires to be arrested, the swollen and infiltrated condition of the parts would still further increase the difficulties of exposing it and ligating it directly. In such case, should efforts at direct ligation prove unsatisfactory, the tampon of Desault might be resorted to, as described in connection with the internal mammary artery. If this should prove inadequate, mediate ligation of the artery, by including it in the loop of a ligature thrown around the adjacent rib, may be done. This method of securing this artery is described as follows by Agnew,[1] who has invented an instrument for facilitating its practice: "A strong, sharply curved needle, with a blunt point having in it an eye for the thread, should be taken. Having introduced a strong thread (silk, catgut, or silver) through this eye, prolong the wound a little posteriorly, and, dipping the point of the needle under the lower edge of the rib, follow closely its inner surface, and, by depressing the handle of the instrument, make the point present, covered by the integuments, at the upper margin of the rib. An incision should now be made so as to uncover the point of the instrument and enable the operator to remove the thread from

[1] The Principles and Practice of Surgery, 1878, i., 329.

its eye, after which the instrument should be withdrawn. The ends may be disposed of by tying them together over a roll of lint, or by passing them through the openings in a bone button, and then securing the knot. Another plan of dealing with the ligature, after thus encircling the rib, is to pass the end which was removed from the eye of the instrument through an ordinary good-sized needle, slightly curved at its extremity, and, reinserting it at the puncture made at the upper part of the rib, carry it between the integuments and the external surface of the ribs, bringing it out at the original wound. This, which is quite easily accomplished, constitutes a subcutaneous ligation without the inclusion of soft parts. The upper puncture should then be closed with an adhesive strip. Ligatures applied in this way unavoidably compress artery, vein, and nerve.

Penetrating Wounds.—Wounds which pierce the pleural sac may either simply open the pleural cavity or may involve the organs contained within the chest to a varying extent. The most numerous class of penetrating wounds of the chest are gunshot wounds. Next to these in frequency are punctured and incised wounds.

The prognosis of penetrating gunshot wounds is very grave. Out of 8,715 cases tabulated in the "Medical and Surgical History of the War of the Rebellion" (Part I., vol. ii., p. 606), 5,260—62.6 per cent.—died. Out of 1,609 cases collected from various authors, and tabulated in the same history, 1,049—65.2 per cent.—died. The course of incised and punctured wounds is much more favorable. Of 291 cases reported by Albanese,[1] of Palermo, only 24—8.2 per cent.—resulted fatally, 8 of which were wounds of the heart, and 4 wounds complicated with wounds of the abdomen, the peritonitis from which caused the fatal result. The great fatality of chest-wounds depends upon the vital importance of the organ wounded and the extent of the wound. Of the intra-thoracic organs, wounds of which may be in any degree affected by treatment directed especially to them in any case, the lungs and the pleura demand most extended notice. Brief notice must be given to possible opportunities that may present for interference in rare cases of heart-wound. Wounds of the thoracic portion of the œsophagus, of the thoracic duct, and of the nerve-trunks that descend through the thorax are beyond the reach of the surgeon. Wounds of the great blood-vessels are quickly and hopelessly mortal. Examination of the opportunities for treatment presented by the heart and its sac, by the lungs, and by the pleuræ, will first be made, after

[1] Transactions International Medical Congress, London, 1881, ii., 438.

which the general cares demanded by penetrating chest-wounds, as a whole, will be considered.

Heart and Pericardium.—Not every wound of the heart results fatally. The statistics of Fischer,[1] for which we are indebted to quotation by Otis (op. citat., p. 530), state that out of 452 cases analyzed, 75—16.3 per cent.—recovered. Many instances are recorded of death occurring some hours or days after the reception of a wound of the heart by a gradual leakage from it, the blood escaping into the pericardium, and also, in some cases, into the pleural cavity through a pericardial wound, and producing death either by the loss of blood, or by the embarrassment to the heart occasioned by the accumulating effusion in its investing sac. If such cases could be recognized before death, with any degree of certainty, their otherwise hopeless course would justify an exsection of the overlying cartilages, an incision into the pericardium, the evacuation of the effused blood, and an attempt to suture the rent in the heart-wall. That the pericardial cavity can be opened for a short time with impunity in the human being, Koenig's case of excision of the sternum,[2] in the course of which both pleural cavities and the pericardium were opened into, has demonstrated. In this case the openings were at once occluded with antiseptic gauze. The dressing was not disturbed for twelve days. Ultimate recovery was secured. Block[3] has farther shown that in dogs, not only can the pericardial cavity be opened with impunity, but the heart may be seized at its apex, and held still sufficiently long for the introduction of a suture, and still have it resume its pulsations. It is not impossible that heart-suture may yet be successfully performed in the human subject.

Lungs.—The wounded lung will collapse more or less closely, according to the size of the aperture in the thoracic wall, and the freedom with which air can pass into the cavity of the chest through it. In rare instances protrusion of a portion of the lung through the external wound has taken place. The lung-wound may bleed, may become inflamed, may be complicated by the retention within it of a foreign body. The bleeding from a lung-wound will exhibit itself both by a bloody expectoration, and by effusion into the pleural cavity. Its arrest must be procured by general measures; absolute quiet and silence; ice, swallowed, and also

[1] *Die Wunden des Herzens und des Herzbeutels. Archiv für klinische Chirurgie*, ix., 571.

[2] *Allgemeine Wiener medicinische Zeitung*, September 25, 1882.

[3] *Gazette Médicale de Strasbourg*, October 18, 1882.

applied to the surface of the chest; ergotine, hypodermically administered; opium; heat and counter-irritants to the extremities. The management of accumulations of blood in the pleural cavity will be considered in another connection. Traumatic pneumonia does not involve large portions of the lung structure, as in the idiopathic variety, but is limited to the vicinity of the wound track. The inflammatory exudation may be absorbed, may be discharged through the bronchial tubes, or may accumulate in the cavity of the pleura. From the latter cavity they will need to be evacuated by incision and drainage.

Foreign bodies embedded in the substance of the lung are not to be searched for, but left to their spontaneous course. Should the patient survive, and continued ill effects be experienced from the foreign body, the propriety of exploratory operation, and of resection of a portion of the lung may yet become a matter of consideration. The experiments of Block,[1] upon animals, in which recovery and survival, in apparently good health, was secured after the removal of from one to four pulmonary lobes, are sufficiently encouraging to suggest the hope that such an operation may be proven to be available for the relief of otherwise hopeless cases of prolonged suppuration and irritation from the retention in a lung of a foreign body.

Hernia of the lung should be treated by carefully cleansing and disinfecting the protrusion, and, if possible, returning it into the thoracic cavity, enlarging as much as may seem prudent the original wound, in order to favor the return. According to Otis (op. citat., ii., 518), there is, however, but a single instance of successful reduction of a traumatic pneumocele without previous ligation of the tumor at its base and excision of the distal portion. If the first attempt to reduce fail, either ligation and excision may be done, or no interference be attempted beyond protecting the protrusion during the course of its becoming adherent to the margins of the wound and its ultimate cicatrization. In most of the recorded cases the former has been done, and without bad results. The material for the ligature should be aseptic, and the stump, after having been disinfected, may be returned to the pleural cavity without hesitation.

Pleuræ.—By the penetration of the pleural sac, air and blood enter its cavity; air escaping again through its external opening may become dif-

---

[1] *Experimentelles zur Lungenresection. Deutsche med. Wochenschrift*, Berlin, 1881, vii., 634–636.

fused among the interstices of the subcutaneous connective-tissue; and, finally, septic inflammation of the pleural membrane itself, with accumulation of inflammatory products in its cavity, may follow.

In general the mere fact of the presence of air and blood in the pleural cavity does not call for active interference unless they accumulate in such quantity as to embarrass the action of the sound lung. The escape of blood to such an amount would be fatal from the loss of blood alone.

Hæmothorax.—Signs of an increasing accumulation of blood in the pleural cavity call for a renewed examination of the wound in the parietes, to exclude a possible hæmorrhage from a superficial vessel. If such should be found, it should be secured by ligature at once. If not, the opening into the thorax should be made sufficiently free, so that the blood being effused into its cavity may escape externally, while the general measures for arresting the hæmorrhage, which have been referred to in connection with bleeding from the lungs, should be adopted. Effusions of blood which have been retained in the pleural cavity and have undergone decomposition are to be removed by incisions through the wall of the chest, and by antiseptic irrigation.

Pneumothorax.—The relief of troublesome pneumothorax is to be accomplished by dilating the external wound so that the escape of air from the wounded cavity may meet with no obstruction.

Emphysema, rare after gunshot wounds, and more frequent after oblique stab wounds, is due to a want of parallelism between the superficial and the deep portions of the parietal wound. The wound should be enlarged sufficiently to make the whole track free and direct. The swollen tissues should be compressed by a bandage; punctures and scarifications may be made if needed, but will rarely be required.

Empyæma and *Hydrothorax.*—Accumulations of fluid, the results of traumatic pleurisy, require thoracentesis for their removal. Simple serous exudation may be removed by aspiration; sero-purulent and sanguineo-purulent collections should be evacuated by free incision of the thoracic wall, irrigation with antiseptic lotions, and drainage until obliteration of the purulent cavity is accomplished. Exsection of a portion of a rib may be done, if necessary to give the required freedom to the opening. The opening should be free enough to admit a finger easily, and to permit the escape of any fibrinous shreds, masses of gangrenous tissue, or foreign bodies that may be loose in the pleural cavity. In resecting a rib, the method of procedure should be as follows: Make an incision for two inches

or more directly over the rib selected, and join this, at its mid point, by another an inch long, carried downward at right angles to it. This should be deepened until the rib has been completely exposed throughout the length of the first incision, and then the periosteum divided in a direction parallel to the long axis of the bone. Then raise it by means of a periosteum-elevator, which is also passed beneath the rib so as to separate it from the deep surface, a manœuvre which is rapidly and easily accomplished. A curved elevator is then slipped completely beneath the rib which is thus raised slightly from those immediately above and below it, and a piece, from one to two inches long, is removed either by cutting pliers alone, or after first dividing the bone half through with a small saw. This is all completed before the pleura, or indeed the deep part of the periosteum, are in any way interfered with. The soft parts being held aside with hooks, the pleura is then incised at leisure, and the opening is enlarged by expanding the blades of a pair of dressing forceps. The risk of wounding the intercostal artery is thus absolutely avoided, and if any vessel be divided, either in the superficial or the deeper structures, it is easily seen and readily secured. Such an opening will admit the finger, if it be thought advisable to introduce it, and in the subsequent progress of the case the removal of the portion of the rib leads to no inconvenience. Antiseptic dressing of the drainage-wound (Chapter X.) should be carefully performed, as directed in the next section for the original wound.

An efficient drainage-tube may be readily improvised in the following manner:[1] Take a piece of pure India-rubber sheeting, $\frac{1}{12}$ inch thick and about $1\frac{1}{2}$ or 2 inches square, and cut a round hole in its centre. Then take a piece of tubing, of the size required, and without holes, and of a length merely sufficient to project into the chest cavity, being from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long—according to the thickness of the chest wall. Split this at one end into four pieces, which are then drawn through the hole in the flat piece of rubber, turned down upon it, and fixed in position by stitches of fine silver wire. The completed tube is shown in Fig. 105. Such a tube will adapt itself to a sinus leading in any direction, and will require no special manœuvres to prevent its slipping into the chest; it may be left beneath an antiseptic dressing for many days at a time, in confidence that it will work well all the time.

General Résumé.—If the external wound is small, with no or only

[1] R. J. Godlee, The Treatment of Empyema. Annals of Anatomy and Surgery, July, 1883, viii., 13.

slight splintering of the bones, and is adapted for primary closure, immediate antiseptic occlusion should be done.

If the wound is extensive, not suitable for primary closure, and complicated by an extensive bone-splintering, it should be enlarged and carefully cleansed by the removal of the splinters of bone, tissue-shreds, clots, or foreign substances that may be entangled in it; sufficient counter-openings should be made to afford effective drainage, and thorough disinfection of the wound and its surroundings should be made. Then thick and extensive layers of antiseptic protective material (Chapter X.) should be applied, with adequate drains in the wound and in the counter-openings. The whole should be secured in place with bandages applied so as to strongly compress the thorax and restrict its movements. To prevent the access of air under the edges of the dressings, an elastic bandage should be carried around its upper and lower borders; to prevent slipping of the dressings up or down, a muslin bandage should be carried once or twice over one shoulder and down under the perineum, and up over the shoulder again, and secured by pins to the upper and lower parts of the dressing, in front and behind. The antiseptic dressings should cover the whole width of the thorax, from neck to navel.

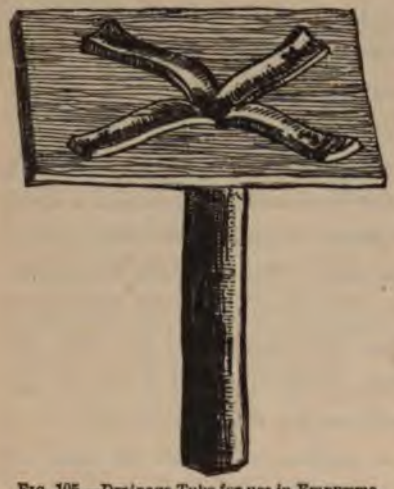


FIG. 105.—Drainage-Tube for use in Empyæma.

Changes of dressing should be made as rarely as possible. Should occlusion not be successful in preventing copious suppuration in the wound-track, more frequent changes of the dressings will be required.

In the primary cleansing of the wound, if foreign bodies present themselves, they should be removed, but no search by probing for a foreign body should be made.

The arrest of hæmorrhage will be attended to as a part of the primary cleansing of the wound which has been described.

CHAPTER XX.

WOUNDS OF THE ABDOMEN—OF THE PELVIS.

Non-penetrating Wounds of Parietes—Arrest of Hæmorrhage—Apposition—*Penetrating Wounds without Injury to Viscera*—The Peritoneal Wound—Protrusion of Viscera—Intestine—Omentum—Other Viscera—*Penetrating Wounds with Injury to Viscera*—Exploration of Abdomen—Diagnosis Positive—Diagnosis Presumptive—Arrest of Intraperitoneal Hæmorrhage—Suture of Visceral Wounds—Lembert's Suture—Jobert's—Emmert's—Gély's—Gussenbauer's—Czerny's—The Continuous Intestinal Suture—Circular Invagination Suture—*Primary Cleansing of Peritoneal Cavity—Drainage—Peritonitis and Septicæmia—Wounds of the Bladder*—External Incisions—Laparotomy—Suture of Bladder—Catheterization—*Wounds of Anus and Rectum.*

Wounds of the abdomen may involve simply the abdominal wall, without penetration of the peritoneal sac; they may penetrate the peritoneal sac without wounding any abdominal viscera; they may involve wounds of any of the viscera. Each class presents certain features in treatment which require special consideration.

NON-PENETRATING WOUNDS OF THE PARIETES.

Arrest of Hæmorrhage.—When arterial bleeding is present, the general rule, that the bleeding vessel shall be exposed in the wound, and a proximal and distal ligature be applied to the divided ends, is imperative. The internal epigastric, the internal mammary, and the internal circumflex iliac arteries, when wounded, may retract within the muscles among which they lie, and cause trouble in securing them; should attempts be made by compression and styptics to control the bleeding, extensive interstitial extravasation would be endangered, entailing suppuration and sloughing, even though the hæmorrhage be primarily checked. Punctured wounds of these vessels are liable to the same danger of hidden extravasation. In cases of penetrating wounds, the blood may flow into the peritoneal cavity and be concealed. In case of a deep wound of the abdominal pari-

etes, involving the muscles, the surgeon should be sure that perfect and definite hæmostasis has been secured before the wound be closed. Every arterial branch that bleeds should be tied, and double ligature of the larger trunks must not be neglected.

Should extravasation of blood among the intermuscular or interaponeurotic spaces have already taken place, the clots should be removed as far as possible, and thorough disinfection of the parts be made. Should the case have proceeded to the point of clot-decomposition and suppuration, free incisions, antiseptic irrigations, and drainage should at once be made.

Apposition.—Wounds in the abdominal parietes require that careful apposition of all the divided structures should be secured, to prevent premature weakening of its structure. Otis remarks, "Later experience attests the utility of deep sutures; it was generally observed during the late war that ventral protrusions were only to be prevented, after extended division of the abdominal walls, by exact coaptation of the divided muscular tissues. The quilled suture answered the best purpose, reducing the extensible cellulo-fibrous cicatrix to the narrowest dimensions. Twice by this means I secured firm cicatrices, without protrusion, in extensive incised wounds in the bellies of horses, where the difficulty of exact reunion is great." The possibility of the regeneration of muscular fibres, and thus the ultimate perfect restoration of the integrity of the wounded part, is an additional reason for great care in securing coaptation. A position which should relax the wounded structures, together with the compression and support of ample protective dressings and a bandage, should not be neglected.

PENETRATING WOUNDS OF ABDOMINAL WALL WITHOUT INJURY OF VISCERA.

Wounds which penetrate the peritoneal cavity, without injuring any contained viscus, may not differ from non-penetrating wounds, except in the addition of the wound in the peritoneum; they may be complicated by protrusion through the wound of some of the abdominal contents; they may be complicated by the entrance of foreign matter or blood into the peritoneal cavity.

The Peritoneal Wound.—This should be closed by being included in the deep sutures introduced for the purpose of closing the wound in gen-

eral. These deep sutures should be inserted rather more than an inch from the border of the wound, and should slope toward the inner surface, yet so as to include, upon either side, a narrow strip of peritoneum. When the sutures are tightened, the included peritoneal surfaces are brought into apposition, and adhere with great rapidity. Whenever edges or surfaces of peritoneum are divided or separated, they should, if possible, be reunited. Peritoneum must be apposed to peritoneum ; the edges should be inverted so that two serous surfaces shall be pressed together, the exact opposite of the conditions required for the union of skin or mucous membrane, union of wounds in which is prevented by inversion of the skin or membrane into the wound. The reparative processes in the serous membrane of the abdomen are identical with those described for the intima of blood-vessels. When the peritoneal margins of a wound are brought and held in apposition by sutures, the effused lymph quickly adheres, fills up the angle of union, and may make so smooth a surface as even to render undistinguishable the line of union. In wounds of the parietal peritoneum, we have the best reasons, clinically, why we should always reunite the severed edges of the peritoneum. As has been pointed out by Sims,[1] if the edges of the peritoneum are not embraced in the sutures that close the abdominal section, a raw surface is left on the inner face of the wound, which immediately adheres to the subjacent parts. If it happens to adhere to the omentum, well and good ; but if to intestine, the result may or may not be fortunate. For, if the adherent intestine happen to be convoluted in such a way as to obstruct the bowel, a fatal result may follow. Sims relates that he has seen three cases in which, while the parietal wound gaped open widely, the peritoneal edges were firmly united. In these cases, if the peritoneum had not been closed, there would have been no union whatever in the line of the abdominal incision.

Protrusion of Viscera.—The viscera most frequently met with protruding through wounds of the abdominal parietes are the small intestine and the omentum. Instances of protrusion of the stomach, liver, spleen, kidneys, and bladder have been noted. Many instances of recovery from the most extensive and aggravated wounds of this character, under very unpromising circumstances, are on record, so that no case of the kind should be despaired of. The following recent cases may be quoted in illustration of the truth of this statement :

[1] British Medical Journal, Dec. 10, 1881, p. 925.

1. Case reported by Simpson,[1] of Michigan. Male, 30 years of age, cut his abdomen open with a razor, while in the woods. Seen by the surgeon four hours after the occurrence. Was then covered by an old bed-quilt, which was adherent to the protruding intestines. Wound was in middle line, eight inches in length, extending from the ensiform cartilage to a point below the umbilicus. Through this a mass of intestines, consisting of eight inches of transverse colon and twelve feet of small intestine and omentum protruded; the intestines were dry and wrinkled, covered with cinders, dust, sand, and a variety of foreign matter which had been rubbed in as the man had rolled over and over on the ground in his agony. Under chloroform, the larger bits of foreign matter were picked off, and the intestines washed in water from a neighboring brook, and the protruding viscera returned. A quantity of blood effused into the peritoneal cavity was mopped out with a handkerchief. The wound was closed by a continuous suture applied so as to include the whole thickness of the wound-edges. Difficulty was experienced in preventing the omentum from protruding while the suture was being applied, and in the lower half of the wound it became adherent to and united with the lips of the wound. The man was then removed in a lumber wagon four miles to a town, and placed on a dirty cot bed in the city fire-engine house. Rapid recovery without an untoward symptom took place, so that he was discharged from treatment on the fifteenth day after the occurrence.

2. The second case[2] is very similar to the first. A male, 55 years of age, attempted suicide, and cut into his abdomen with a large knife four successive times. When first seen, three hours after the accident, the patient was found lying on the dirty floor of a cattle-hut, in a fainting state, with all the small intestines and the whole omentum majus protruding out of a clean-cut wound which extended from the scrobiculus cordis far below the umbilicus. There were seen also three other smaller wounds, all of them perforating the abdominal wall. The protruded parts, which were covered with mud and blood, were washed with tepid water and returned, and then all the wounds closed with silk sutures, and dressed with cold water. Three weeks later the patient left the hospital, having recovered without any complication except a small abscess in the abdominal wall near the largest wound.

Out of 307 cases of penetrating incised wounds of the abdominal cav-

[1] Medical Gazette, New York, 1882, p. 225.

[2] Sarmatsky, *Vrachebniya Vaidomosti*, St. Petersburg, 1882, No. 16.

ity reported by Albanese,[1] of Palermo, in only 6 instances did death result from simple diffuse peritonitis. In these cases, protruding intestinal loops were always carefully washed with carbolated water, and any wounds in the intestines sutured before the protrusion was returned.

In general, the rule of treatment in this class of cases is to cleanse and disinfect the protruding viscus as carefully as possible, and return it into the abdominal cavity, after which the wound should be treated as one without protrusion. Attention must be directed, however, to modifications of this rule demanded in certain circumstances.

Intestine.—So large an amount of intestine may have escaped through the wound that it can no longer be passed back through the opening by which it escaped. In such a case the wound must be enlarged until the return of the protruding intestine is possible; care should be taken to make the incisions at those portions of the wound which resist distention and act as agents of constriction. The return of the intestine should be followed by insertion of the finger to determine with certainty that the gut has been replaced in its proper cavity, and not crowded between the peritoneum and the superficial tissues.

The difficulty in reduction may depend on the distention of the bowel by flatus. If so, an attempt to press it back into the portion of intestine within the abdomen should be made. If this is unsuccessful, and the protrusion is great, with excessive distention, the bowel should be punctured with an aspirating needle through which the gas may escape.

The intestine may have been strangulated by the constriction of the wound through which it has been forced. If, after the constriction has been relieved, the circulation in the previously strangulated loops resumes its natural course, reduction of the gut, and closure of the wound should be made. If gangrene is already present, or if the feeble and imperfect return of the circulation, after dividing the stricture, indicate that it is inevitable, the bowel should be left in the wound, to the margins of which it will have contracted adhesions, an incision should be made into the bowel and an artificial anus created.

Omentum.—Protruding omentum, which cannot be readily replaced, should be ligated at its base and cut off; if an aseptic ligature has been employed, the stump may be dropped back into the abdomen, and the abdominal wound may be closed; if an ordinary ligature be used, the

[1] Transactions of the International Medical Congress, London, 1881, ii., 437.

omentum must be left in the wound, and healing by granulation awaited. Protruding omentum that is very dirty, that is congested in any degree, or into whose substance extravasations of blood have taken place, should be excised. If the size of the omental mass, that is to be excised, be considerable, a double thread should be passed through its base, and each half tied separately.

Protrusion of other Viscera.—Protrusions of the stomach are to be treated in accordance with the rules for the intestines.

In cases of protrusion of the bladder, evacuation of the urine should first be secured by the introduction of a catheter, after which its reposition may be effected without difficulty.

Protrusions of portions of the spleen, or of the liver have occurred. The general treatment of such protrusion should be the same as that given for protruding omentum.

Two cases of complete protrusion of a kidney through a wound have recently been recorded.[1] In both cases a ligature was thrown around the pedicle formed by the vessels and ureter, and the kidney removed. Recovery ensued.

PENETRATING WOUNDS OF THE ABDOMINAL WALL WITH INJURY OF VISCERA.

In the treatment of this class of wounds, the surgeon will need to specially consider the subjects of exploration of the abdominal cavity, arrest of intraperitoneal hæmorrhage, suture of visceral wounds, primary cleansing of the peritoneal cavity, secondary cleansing or drainage, and secondary inflammatory and septic complications.

Exploration of the Abdominal Cavity.—The evidences that an abdominal viscus has been wounded may be either positive or presumptive. The escape through the opening in the parietes of the contents of the alimentary tube, of the bile or of the urine, or the protrusion externally of the wounded viscus, so that the wound is subject to actual inspection, alone can be considered as positive proof of visceral injury. When any of these conditions are present, the duty of the surgeon is, clearly, to enlarge the opening in the abdominal wall, or to make a new one in a more favorable location, sufficiently to admit of examination of the viscera in the track of

[1] Brandt: *Wiener Med. Wochenschrift*, 1873. Marvand: *Recueil de Mém. de Med. de Chirurg.*, etc., 1875, xxxi., 502.

the wound, to detect and ligate bleeding vessels, to suture intestinal rents, and to thoroughly cleanse the peritoneal cavity of extravasated matters.

In the great majority of cases of visceral wound, however, positive evidence is wanting, and simply a more or less strong presumption of the fact of the wound exists. In these cases it should first be established, by superficial exploration, that penetration of the peritoneal cavity has taken place. In this respect an exception should be made to the general rule given in the case of gunshot wounds to abstain from all primary exploration of their track. Gunshot wounds of the abdominal walls should be explored in all cases, as soon as the necessary requisites of aseptic cleanliness can be complied with, sufficiently to determine whether they do or do not penetrate the peritoneal cavity.

The fact of penetration having been established, the further course to be pursued becomes a matter of grave consideration, whenever signs of already impending dissolution do not absolve the surgeon from all responsibility. With but few exceptions, this class of wounds are gunshot wounds. A policy of non-interference, and of expectant treatment by rest, cold, and opiates has been pursued in the past in the treatment of the cases under discussion. Notwithstanding this treatment, 87.72 per cent. of all penetrating gunshot wounds of the abdomen, during the war of the Rebellion, terminated in death. During the Crimean war, 91.7 per cent. of the cases among the French, and 92.5 per cent. among the English, died. Of the cases that recover, the larger proportion are among those in which the protrusion of the viscera, or the adhesion of the margins of the internal visceral wound to the margins of the external wound so that the contents of the viscus escape externally, relieve the surgeon from all doubt as to the course he should pursue. Of the few cases that remain, in some the recovery has taken place though positive evidence of visceral penetration has been given by the subsequent voiding of the bullet *per anum*, and in yet others in which the symptoms have afforded strong presumptive evidence of visceral wound, as in the following case, reported by Schapps:[1] a male, aged twenty years, was admitted into St. Vincent's Hospital, New York, in the service of Dr. Chas. Phelps, May 26, 1880, having been shot by a pistol at a distance of three feet. The bullet penetrated the abdominal wall two and a half inches above and to the left of the umbilicus. General condition when admitted fair, but within half an hour experienced great de-

[1] Annals of Anatomy and Surgery, 1881, iv., p. 88.

pression of vital powers, and vomited considerable blood. Ice, stimulants, and opium were given. He was discharged on the twenty-second day thereafter, cured.

It should also be remarked that instances have been recorded in which the abdominal cavity has been traversed by a bullet, or transfixed by a weapon, without injury to any of its viscera.

In any individual case, the possibility that it may prove to be one of the rare exceptions to the general rule of fatality, will have its influence on the decision of the surgeon as to the course which he shall pursue.

The cause of death in the fatal cases is either shock, hæmorrhage, septicæmia, or septic peritonitis. Death from the first two causes is speedy, so that, except in rare instances of slowly accumulating blood-extravasations, they do not require special consideration here. The two latter causes of death, septicæmia and septic peritonitis, are more slow in their operation, and hence engage the more particular solicitude of the surgeon in the treatment that he may give. Most important of all would be their prevention, but in these injuries the cause is inherent in the wound itself, from the extravasation of the septic contents of the wounded organs into the peritoneal cavity. Free incision, exploration, disinfection, and drainage constitute the treatment for similar conditions in other regions of the body and would be resorted to in all cases of penetrating wounds of the abdominal cavity were it not for the special dangers which such practice involves. These are the shock of the incision and the handling of the abdominal contents, the danger of awakening fatal inflammation by the operation itself, the possibility of disturbing repair which if left alone would have accomplished recovery, and finally, the possibility of overlooking wounds from which subsequent extravasations would occur.

In forming his final conclusion as to the course which he should pursue in the treatment of those cases in which presumptive evidence only exists as to the occurrence of visceral injury, these dangers attending the procedure of incision of the abdominal wall, exploration and cleansing of its cavity, are the only conditions that can weigh for much. They have been sufficient, heretofore, to deter from its practice. The great proportion of recoveries, however, which have followed the free abdominal incisions, and the prolonged manipulations, and the often great traumatism, inflicted upon the abdominal viscera, in the operation of ovariotomy, as performed by many surgeons, has demonstrated that less danger attends mere traumatic injuries of the peritoneum than had been supposed; the dangers of

septic infection have also been more clearly defined by the experience of ovariotomists. In view of the more accurate knowledge now possessed as to the management of peritoneal wounds, encouragement is given to a more ready and frequent resort to immediate ventral incision for purposes of exploration and cleansing in cases where the symptoms establish a strong presumption of visceral injury. The danger that by such procedure adhesions would be broken up, which if let alone would have accomplished spontaneous recovery, is too infinitesimal to be permitted to have any weight; while the final danger that possibly some wound might fail to be detected and secured, as the result of which all that had been done would be useless, should stimulate rather to increased thoroughness in the exploration than to refusal to attempt it at all. In this connection the following language of J. Marion Sims [1] may be quoted :—

"I have the deepest conviction that there is no more danger of a man's dying of a gunshot or other wound of the peritoneal cavity, properly treated, than there is of a woman's dying of an ovariotomy, properly performed. Ovarian tumors were invariably fatal, till McDowell demonstrated the manner of cure, which has now reached such perfection that we cure from 90 to 97 per cent. of all cases. And by the application of the same principles that guide us in ovariotomy to the treatment of shot wounds penetrating the abdominal cavity, there is every certainty of attaining the same success in these that we now boast of in ovariotomy."

In any exploration of the peritoneal cavity, the surgeon must observe every precaution lest he himself, in his manipulations, introduce septic matter. Every precaution of asepsis should be rigidly observed in the persons of the surgeon and of his assistants, and in his sponges, instruments, and appliances. The external surface of the abdomen must be carefully cleansed and disinfected, and the subsequent dressings should be antiseptic in character.

Arrest of Intraperitoneal Hæmorrhage.—Whenever evidences of intraperitoneal hæmorrhage are present, there is but one resource, the enlargement of the external wound, or the making of an incision through the abdominal wall in a more suitable situation, and the exposure and ligation of the bleeding vessel. Aseptic silk or catgut should be used; the ligature should be cut short and left in the peritoneal cavity.

Parenchymatous hæmorrhage from the tissue of a wounded liver, spleen or kidney should be arrested by the actual cautery.

[1] British Medical Journal, March 4, 1882.

Suture of Visceral Wounds.—In suturing intraperitoneal wounds of the alimentary canal or of the urinary or gall bladders, the apposition of the serous surfaces adjacent to the wound edges, rather than of the wound edges themselves, is of the greatest importance. An effectual method of accomplishing this in ordinary wounds is the method of Lembert,[1] known as "Lembert's suture" (Figs. 106 and 107).

Fig. 106.

Fig. 107.

Fig. 106.—Lembert's Suture. A, exterior view of suture, in place; B, transverse section; C, interior view, showing incurving of the serous coat.

Fig. 107.—Lembert's Suture as Applied to a Transverse Wound; Exterior View.

The suture is applied as follows: at a point about one-third of an inch from the edge of the wound the peritoneal coat is pierced from without inwards (Fig. 107, *a*), the needle is then caused to glide between the serous and mucous coat for one-half the distance between the point of entrance and the wound-margin, it is then brought out through the serous coat again (Fig. 107, *b*), carried across the wound, and entered on the other side (Fig. 107, *c*), at a similar distance from the wound margin and the same manœuvre repeated in reverse order. When the loops are tied, the tension causes the edges to be inverted as a natural consequence, and the serous surfaces are held in secure apposition. The stitches should be in-

[1] Lembert: *Sur l'enterorhaphiè. Repertoire d'anat., de physiol. pathol.*, 1827.

troduced quite closely together, at intervals not exceeding a quarter of an inch, in order that, should distention of the bowel by gas occur before firm adhesion of the bowel has taken place, no gaping even then should be possible. The threads should not be drawn so tightly as to constrict the tissues, and cut them through, but simply firmly enough to keep the parts in apposition. The threads become imbedded in the plastic exudate that forms the new bond of union, and give no further trouble.

The choice of a material for the suture, providing it is aseptic, may be either silk or catgut. Surgeons differ in the preference to be given to these materials. Czerny, Billroth, Madelung, Baum, Bouilly, and others, consider silk as the best. Dittel, Schede, Julliard, Rydigier, and others prefer catgut.[1] The speedy softening of catgut has been charged with exposing wounds in which it was employed to the danger of being left without support too early, but without sufficient reason, if it has been fastened in the first place with care, for so rapidly does the adhesion of the serous surfaces take place, that no danger is to be feared from the softening of the catgut. The disasters which have taken place have been due either to lack of care in the knotting of the suture, or to sloughing of the intestinal wall. Those who advocate the use of silk find their chief reasons for the preference in the fact that its application is more easy, and a finer needle may be employed with it, points which, though apparently trivial, are of much practical importance.

Ordinary round sewing needles, neither flattened nor with cutting edges, should be used for introducing the suture, in order that the wound made by the needle may be as small as possible, and free from hæmorrhage.

During the application of the suture, it would be best that, if possible, the wounded part be drawn out of the abdomen, and the wound in the parietes of the abdomen kept closed as much as possible by the hands of an assistant, or better, by a sufficient number of temporary deep sutures to lessen the amount of exposure of the abdominal contents.

Modifications of the suture of Lembert have been proposed by Jobert, Emmert, Gély, Gussenbauer, and Czerny.

Jobert carried his needle through the mucous, as well as the serous coat of the viscus, puncturing the inverted edges of the wound in their whole thickness (Fig. 108, A, B, C).

[1] Bouilly and Assaky: *De la résection circulaire et de la suture de l'intestin*, etc. *Revue de Chirurgie*, 1883, p. 383.

When an irritating thread must be used, and it is wished that the suture may cut through and ultimately fall into the lumen of the viscus, this method is to be adopted, and the sutures should be drawn very tightly.

Emmert's suture was devised to overcome a presumed objection to the suture of Lembert that it did not have sufficient hold upon the tissues, and that the cicatrix projected too much into the interior of the viscus.

The method of its application is shown in Fig. 109. The threads are carried through the whole thickness of the visceral wall. A series of in-

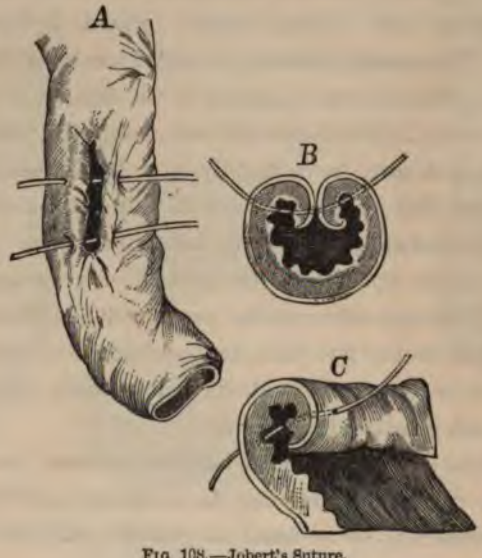


FIG. 108.—Jobert's Suture.

terrupted stitches result by tying together the opposite threads, *a*, *a* and *d*, *d*. It is more intricate and tedious of application than the suture of Lembert or of Jobert, while these have been found to be sufficiently secure.

The suture of Gély (Fig. 110) is executed with a long thread, each extremity of which is armed with a needle. The whole thickness of the wall of the viscus is pierced about one-third of an inch from the wound-margin, at one end of the wound (Fig. 110, *a*) from without inward, the thread is then carried laterally and parallel with the edge of the wound for about one-third of an inch, and then brought out again the same distance from the wound margin as before (Fig. 110, *b*). This procedure is repeated with the second needle on the opposite edge, at "*c*" and "*d*;" this done, the threads are crossed over the gaping wound; the needle

which found an exit at "*b*" is now introduced at the point "*d*" of the opposite side, and *vice versa* with the other needle. Thus the surgeon continues, till the entire wound is closed by the suture. The extremities having been drawn tight, the knot is tied and cut short. The result is excellent, but the same criticism is applicable to this as to the suture of Emmert.

Czerny's suture. If, in addition to the ordinary Lembert suture, the cut edges of the peritoneal coat be first sutured together by a row of fine sutures, one of which is seen already placed in Fig. 107, and then the in-

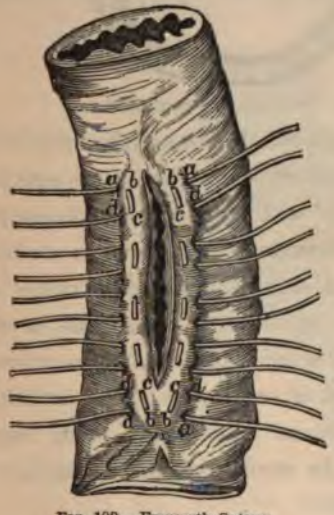


FIG. 109.—Emmert's Suture.

FIG. 110.—Gély's Suture.

vagination and suture of the more distant portion of the serous coat be done as usual, the sealing up of the wound will be doubly insured. This is the suture of Czerny.

Fig. 111 gives a diagrammatic representation of a transverse section of a bowel to which this suture has been applied.

Gussenbauer's suture is essentially the same, differing only in that both the internal and external stitches are made with the same thread, the in and out course which the thread is made to take, causing a figure of 8 to be described by it, are seen in the diagram, Fig. 112.

More simple, and more quickly and easily executed than any of the methods which have been described, and in all ordinary longitudinal wounds of the intestine or bladder, sufficiently secure and reliable, is the ordinary continuous suture (Fig. 113), applied with an over and over

stitch, care being taken to tuck in the edges so as to invert the serous edges, and bring a line of serous membrane into apposition as the thread is drawn tight. In many of the accidental wounds which may demand

FIG. 111.—Czerny's Intestinal Suture.

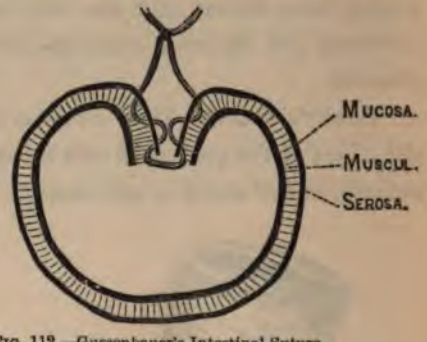


FIG. 112.—Gussenbauer's Intestinal Suture.

the application of an intestinal suture, the conditions may be such as to make the more complicated sutures difficult, if not impossible, of practice. In such cases the continuous suture may be used with every confidence of a good result. Nussbaum[1] expresses a decided preference for the simple continuous suture, asserting that it is applicable in transverse, as well as in longitudinal wounds, and that, even where a complete solution of continuity of the intestinal tube exists, it answers all demands, being easily executed, and in its results not inferior to any of the other methods.

FIG. 113.—The continuous intestinal suture.

The suturing together of the divided portions of an intestine, when complete division of the tube has occurred, requires further consideration. If, in a given case, which is the upper and which the lower portion of the tube can be positively settled, Nussbaum advises that the end of the upper tube be invaginated into that of the lower, whose edge is first turned in so that serous surface shall be apposed to serous surface, and the two be secured after the method of Jobert. Fig. 114, A, B, shows the relation of the two ends to each other when invaginated. The steps of the procedure are thus described by Nussbaum:—First, the two divided extremities, "*x*" the

[1] *Die Verletzungen des Unterleibes. Deutsche Chirurgie, Lief.* 44, p. 159.

upper portion, and "*y*" the lower portion, are dissected up from the mesentery; secondly, the upper portion, "*x*," is invaginated by means of two sutures into the lower tube, "*y*" (see Fig. 115). The upper tube is supplied with sutures, affixed to opposite sides (Fig. 115, *a a*), about two-thirds of an inch from the edge of the wound. Each extremity of the suture is armed with a needle, each of which are then made to pierce the doubled-in lower portion, "*y*" (Fig. 115, *b*, *c*, and *d*, *e*, the punctures *b* and *c*, and *d* and *e*, being situated from one-third to one-half an inch from each other). The next step is the tying of the sutures, *b* and *c*, whereby the intestine "*x*" is drawn into the lumen of the tube "*y*." At

FIG. 114.—Jobert's Method of Invagination.

the points *d* and *e*, the procedure is repeated. The tension should be moderate, otherwise the nutrition of the surrounding tissues will be disturbed, and gangrene result. The operation is completed by the introduction of the necessary number of sutures to keep the ends of the bowel in position and prevent extravasation. The continuous, or some form of the interrupted suture may be used. Bouilly and Assaky (op. citat.) reject the method by invagination, as long, difficult of execution, and liable to be followed by symptoms of internal obstruction, and express their belief that the suture of Lembert is sufficient in every case, provided the threads are sufficiently near together. From them may be quoted the following practical directions in performing the operation:

One or two points of suture should be first applied upon the lips of the triangular wound in the mesentery, two suffice usually to approximate these parts up to the concave border of the intestine. It is well to place a point

of suture at the place where the mesentery is to be attached to the intestine and to secure it to the intestinal wall. The first point of intestinal suture, the highest, is placed quite near the new mesenteric insertion; immediately afterward the second thread is placed at a point diametrically opposite, that is, on the convex border of the intestine. These two threads, in position and knotted, hold the intestinal ends well in the positions which they should occupy and facilitate much the introduction of the other threads; these are successively introduced, working from the concave border to the convex. To reach the posterior surface, it is necessary to raise up the loop already sutured. The introduction of the posterior

FIG. 115.—The Invagination Suture.

FIG. 116.—The Invagination Completed.

series of threads is particularly difficult near the insertion of the mesentery, where, indeed, special care should be exercised. Each thread should be tied as it is put in place. The number of points of suture should be considerable. The threads should be very near together, for points separated by an interval of one or two lines, where the intestine is collapsed, would be found to be distant from each other a quarter of an inch and more when that state of tympanitis occurs, which always follows, though perhaps only temporarily, every intraperitoneal operation. The needle should not pierce the intestinal tissues more than a third of an inch away from

the cut margin. Should a decided difference in the calibre of the two ends exist, the larger might be retrenched by the removal of a longitudinal gore from its wall and then the apposition and suture of the two ends be effected, or the union of the two might be accomplished as far as possible, and then the gaping portion left be secured in the external wound and a temporary artificial anus formed.

Primary Cleansing of the Peritoneal Cavity.—In all wounds attended with extravasation into the peritoneal cavity of matter, either septic or prone to become septic, the most thorough and scrupulous cleansing of the cavity must be practised. The external wound must be enlarged, if necessary, sufficiently to admit of the complete performance of this duty. After all hæmorrhage has been absolutely and definitely arrested, and suture of the visceral wounds has been accomplished, all foreign matter, blood and serum must be removed. For this purpose irrigations and spongings may be used. The irrigating fluid should be blood-warm, and should be made to approximate the specific gravity of the serum of the blood, by the solution in it of a small quantity of common salt. The nozzle of the irrigating tube should be introduced deeply into the peritoneal recesses both of the abdomen and of the pelvis. While the irrigation is being practised, the position of the patient can be changed so as to facilitate the free escape of the irrigating fluid. Sponging should be done by soft and pure sponges, secured to a sponge-holder or grasped in a forceps, by which they are carried down to the farthest recesses of the peritoneum. No loose sponge should be thrust into the abdominal cavity, on account of the danger of its being overlaid by the intestinal folds and left in the cavity. The sponging should be continued until the peritoneum is clean and dry. In the absence of the desired purified sponges, sponging must not be dispensed with, removal of intra-peritoneal effusions must in all cases be made as perfectly as possible, with the best means at the command of the surgeon.

Drainage.—The conditions which the peritoneal cavity presents are such as to alter the relations of artificial drainage in the case of wounds within it. As has been pointed out by Mr. Lister,[1] the large size of the cavity prevents the occurrence of tension within it, though copious secretion may take place. The absorptive powers of the serous lining suffice, in many cases, to rapidly remove effusions, and thus to prevent their accumulation and putrefaction. The natural great vital resisting power

[1] Transactions International Medical Congress, 1881, vol. ii., p. 370.

of the peritoneum enables it to control and overcome septic influences to a certain degree. On the other hand, special disadvantages attend the use of artificial drains in wounds of the abdominal cavity. They have been summarized by Knowsley Thornton [1] as follows:

1. Dangers of admitting infective material through the tube.

2. Danger from the removal of serum and blood from the peritoneum in an exhausted patient. Aseptic peritoneal contents are reabsorbed and feed the patient.

3. The tube causes a weak spot in the ventral wall for subsequent hernia.

4. The slow healing of the tube-opening prolongs convalescence, and exposes the patient to the additional risks of an open wound.

The practical conclusion may be accepted that when thorough primary cleansing of the cavity has been done, the wound may be closed with every expectation of future freedom from septic infection. The expression of Spencer Wells [2] is, that in his cases of abdominal section, since he has adopted antiseptic precautions, either intra-peritoneal fluids do not form, or, if they do, they do not putrefy, but are absorbed without doing any harm. The rule adopted by Keith,[3] in cases of ovariotomy, is to use a drainage-tube whenever a constant oozing of blood continues from surfaces exposed by the tearing away of adhesions, so as to prevent the abdomen from being dried by sponging. His language is: "Tie everything; stop the bleeding and leave the abdomen dry; and when you can't leave it dry, put in a drain. Of course this applies to bad cases only; and you will not get bad cases well without draining." The following practical observations, by the same surgeon, as to the manner of using drainage-tubes, may be quoted in addition: "I put the drainage-tube through the abdominal wall. It is a small, straight glass tube, adapted to the depth of the pelvis. You must see that it does not press injuriously on the rectum. I feel how it is lying on the rectum, and if it is making pressure, I shift it up a little bit. I cover it with a sponge, and wrap that in an India-rubber cloth for cleanliness. Doing this way you may often drain for a week and not a drop escape on the dressing or the dress, it being all collected in the sponge. I examine, usually, within four or five hours to see if anything is on the sponge. When the stuff will not run out itself, I get it out by putting a syringe in the tube and sucking it out. I change the sponge

[1] Ibidem, p. [illegible] [2] Ibidem, p. [illegible]

[3] American Practitioner, November, [illegible]

night and morning. I formerly kept the drainage-tube in six days or a week, till the serum got quite sweet and pure ; but now I take it out generally within forty-eight hours. If the amount comes down to a drachm or two, I don't mind taking the tube out, and that without any kind of precautions. After all, though, you must be governed by the quantity that comes."

The application of the fruits of the experience of ovariotomy wounds to the treatment of accidental penetrating wounds of the abdomen is direct and immediate. Whenever from the nature of the wound, or the circumstances attending it, all fluids likely to become septic are not removed in the primary cleansing of the peritoneal cavity, their subsequent escape by drainage must be provided for. The drainage-tube may be inserted either through the original accidental wound, or through one made by the surgeon, as the conditions of the special case may dictate.

Peritonitis and Septicæmia.—The so-called traumatic peritonitis is in all cases a septic inflammation, and kills quickly by the rapid absorption of the abundant septic products—ptomäines—which are drank up quickly by the serous membrane as they are generated in the copious inflammatory secretions. The one imperative thing to be accomplished by way of treatment is to secure the immediate removal of the poisonous exudations. This may require a reopening of the abdomen, repetition of the irrigations, and more effective provisions for drainage. The presence of diffuse peritonitis is not a counter-indication to such opening and cleansing, but, on the other hand, is a condition that directly calls for it.

WOUNDS OF THE PELVIS.

The wounds of the pelvis of which special mention must be made are those of the bladder, and those involving the rectum and anus.

Wounds of the Bladder.—The wounds of this organ may be caused by internal rupture without external wound; may be complicated by external wound; may be inflicted by the surgeon. Special indications to be fulfilled in their treatment centre about the prevention and treatment of the disturbances caused by the extravasation of the contents of the organ. They are: (1) To remove, as soon as possible, extravasated urine. (2) To prevent further escape of urine into surrounding connective-tissue or peritoneal sac. (3.) To meet such symptoms of shock, peritoneal inflammation or urinary infiltration as may appear. The course to be pursued in

meeting the two first indications will vary according as the wound is extra- or intra-peritoneal.

In extra-peritoneal wounds, the removal of extravasated urine requires free and deep incisions into the infiltrated tissues.

In intra-peritoneal wounds, the conditions are identical with those already discussed in connection with wounds of the hollow viscera of the abdomen, and the same method of procedure must be adopted, free external incision of the abdominal wall, suture of the rent in the viscus, and most careful cleansing of the peritoneal cavity of all extravasated matters. The well-known case reported by Walter,[1] of Pittsburg, illustrates the value of laparotomy and cleansing of the peritoneal sac, although it is not beyond criticism, since the suture of the vesical wound was neglected, happily, however, without evil result in this instance, owing to the location of the wound in the fundus, and the continuous use of the catheter. In this case a man 22 years of age, had received a blow on the hypogastric region and immediately felt a sharp pain with an urgent desire to urinate, which he could not accomplish. After some hours, the belly began to swell, the pulse became small and frequent, and the respiration rapid. A catheter brought away a minute quantity of bloody urine. Ten hours after the injury, no urine passing by the catheter, the abdomen was opened in the linea alba by an incision beginning one inch below the umbilicus and terminating one inch above the pubes, to the extent of six inches. The intestines were found inflated, their peritoneal coat, as well as that lining the interior of the abdominal walls, already showing evident marks of congestion. A soft sponge was then cautiously introduced into the abdomen, with which the extravasated fluid, amounting to nearly a pint, consisting of urine and blood, was carefully removed from the pelvis, and between the convolutions of the bowels. A rent was found at the fundus of the bladder, two inches in extent. The cavity of the abdomen being cleansed of the noxious agent, the wound of the bladder was left to itself, as no urine was seen to escape from it. The abdominal wound was closed by strong Carlsbad needles, secured by silver wire (only skin and fascia being stitched, while the peritoneum was left untouched); a flannel bandage encircled the whole abdomen. The patient awakening from the anæsthetic sleep, felt relieved of pain and the desire to urinate, so distressing before the operation; vomiting did not return; opium in one-grain doses was ordered; abstinence of drink and perfect quietude of body, with

[1] *The Medical and Surgical Reporter*, Philadelphia, February, 1862.

retention of the catheter, were strictly insisted upon. He soon began to doze, had a comfortable night, was free from pain the next morning, complaining only of soreness in the abdomen without tympanites, sickness or calls to urinate; thirst less urgent. The treatment being vigorously continued, for drinks, iced barley-water, water only in very small quantities with pieces of ice, being allowed. No unpleasant symptom followed; urine in small quantities, but free of the admixture of blood passing by the catheter. On the third day the intervals between the doses of opium were lengthened to two hours; on the fifth, to three, and thus gradually decreased, as all signs of inflammation had passed. At the end of a week the abdominal wound appeared to be closed by first intention; the stitches, however, were not removed till a week later. The gum-elastic catheter was replaced by a new one every two days, and was not withdrawn for two weeks after the injury had been received, and then only for a short time. At the expiration of two weeks, with the absence of all pain and tenderness, opium was omitted. The intestines were relieved by warm water injections on the tenth day, when mild nourishment was ordered. Between the second and third week, the catheter was permanently withdrawn and introduced only every four hours for the evacuation of urine. After the third week, the patient left his bed. The recovery was permanent, so that he returned to his work, feeling no embarrassment in the urinary functions.

In two other recorded instances,[1] abdominal incision has been done for the removal of urine extravasated into the peritoneal cavity. In both these cases, however, the operation was delayed much longer than in the case of Walter, until dangerous symptoms were well developed. Willett operated thirty hours, and Heath forty-two and a half hours after the injury. In both cases suture was attempted, but, as the result proved, was done imperfectly. In the case of Willett, the patient having died twenty-three hours after the operation, the autopsy showed "the opening in the bladder everywhere well closed except between the two posterior stitches where there was an orifice through which water injected *per urethram* escaped very freely." Heath's patient lived more than four days. A continuous catgut suture had been employed. Autopsy showed that it had given way

[1] A. Willett: Abdominal Section in a Case of Ruptured Bladder. St. Bartholomew's Hospital Reports, 1876, xii., pp. 209–222. C. Heath: On the Diagnosis and Treatment of Rupture of the Bladder Medico-Chirurgical Transactions, 1879, lxii., p. 335.

at its lower end, and permitted the wound in the bladder to gape throughout the lower third of its extent.

The advantages offered by laparotomy in cases of wounds of the intraperitoneal portion of the bladder are thus enumerated by Vincent:[1] "With laparotomy a complete examination of the wounded region can be made, and the existence, the location, the extent, and the conformation of the solution of continuity experienced by the urinary reservoir determined; the existence and nature of complications can be seen, if a vesical artery is wounded, or any of the vascular trunks of the region have been torn, they can be ligated; if intestinal loops have been perforated, they can be sutured, with or without enterectomy; if the rectum has been perforated—a frequent event—the breach which is found can be sutured; if a splinter, from a fracture of one of the pelvic bones, projects against the bladder and is tearing it, it can be extirpated, resected, or reduced, as the case may be; if a foreign body has remained in the peritoneal cavity, it can be taken away; if the wounding agent has lodged in the walls of the bladder, or has fallen into its interior, or has become fixed in the walls of the pelvis, it may be extracted at once, which will prevent those fistulæ, those suppurations, those lithic concretions which, when they do not induce death, necessitate later, sometimes after many years of suffering, recourse to the knife, the lithotrite, or the lithotome. With laparotomy the urine can be completely removed, together with the effused blood, all the liquids and clots which may be found in the peritoneal cavity, everything which has been soiled by the urine can be disinfected; in a word, a complete antiseptic toilet of the peritoneum can be made; with laparotomy, finally, the source of urinary extravasation can be absolutely suppressed by careful suture of the bladder; a catheter retained in the bladder cannot replace the suture, this is evident."

As a final estimate of the necessity and value of laparotomy when extravasation of the urine into the peritoneal cavity has taken place, the following is the conclusion of Stein:[2]

"Both clinical and experimental experience teach that the danger to life is not in the laparotomy, but in the presence within the peritoneal cavity of a decomposable and septic fluid, and, when this is removed

[1] *Plaies pénétrantes intrapéritonéales de la vessie. Revue de Chirurgie*, 1881, i., p. 572.

[2] A Study of Rupture of the Bladder, etc. Annals of Anatomy and Surgery, 1882, vi., 59.

shortly after such extravasation has occurred, laparotomy may be practised with almost a certainty of success. The disposition of the bladder-wound to union is so great that it may be regarded as certain if the edges of the same are accurately brought together, while the danger to life from wounding of the peritoneum is in itself very slight."

When an intraperitoneal wound of the bladder has been suffered, the more speedily the removal of the intraperitoneal extravasations by laparotomy, and the closure of the wound by suture, is effected, the greater will be the probabilities of a successful issue. Though it should have been delayed until severe inflammatory and septic conditions have already developed, the incision of the abdominal wall, the removal of effusions already present, free irrigations and adequate drainage, may still afford a possibility of recovery from what would otherwise pursue an inevitably fatal course.

Suture of the Bladder.—The unfortunate result of the attempts at suture in the cases of Willett and of Heath may serve to enforce the necessity of caution and thoroughness in applying the suture to a bladder-wound. Vincent (op. citat.) urges the adoption of the method of a double row of sutures, one at the edges of the wound, but excluding the mucous coat, and another row which pierces the serous coat a little distance from the edges of the wound, by which a more extensive turning in and apposition of the serous membrane is accomplished. This is the method already described on a previous page (363) as Czerny's modification of Lembert's suture, which see.

The double row of sutures closely set should be employed, but the suggestion of Nussbaum, in connection with intestinal wounds, to apply the suture as a continuous suture in each row, should be followed, on account of the greater certainty, ease, and speed with which it can be applied to a deep-seated part like the bladder. Aseptic silk should be used for the ligature material.

The number of cases has already become considerable in which suture of the bladder has been done, with recovery, in cases of wounds of the bladder inflicted by surgeons during the removal of pelvic and abdominal neoplasms.

Catheterization.—Free and uninterrupted drainage of the bladder by continuous retention of a catheter in the bladder through the urethra should be maintained for a week or ten days after the injury. The catheter should be soft and flexible, open at the end, and its end should

reach just within the vesical orifice. It should be removed, washed, and returned once daily during the period of retention. For some time, a week or more, after its continuous residence in the bladder is dispensed with, it should yet be used several times daily to remove the urine, during which time no effort to urinate should be made by the unaided contraction of the bladder.

Wounds of Anus and Rectum.—Wounds involving the lower end of the alimentary canal must be treated as open wounds. In order to preserve them from sepsis it is necessary that the wound cavity be kept packed with energetically antiseptic absorbent material and that the function of defæcation be kept in abeyance. The lower bowel should be thoroughly washed out with a carbolic or corrosive sublimate solution, and the movements of the bowels checked by opium. The wound itself should be freely irrigated with an eight per cent. solution of chloride of zinc, after which the antiseptic absorbent selected should be lightly packed into the wound so as to reach every recess. Iodoform gauze, bags of aluminated charcoal or sublimated coal ashes, may be selected according to the convenience of the surgeon. These should be covered in by a plentiful layer of purified cotton wool, over which a layer of impermeable tissue should be placed, the whole kept in position by a T-bandage. Whenever a movement of the bowels becomes necessary, sufficient of the dressings must be removed to permit the issue of the fæcal matter, after which the bowel should be cleansed and the wound redressed as at first. When the wound has become a superficial granulating surface, the rigid antiseptic efforts may be relaxed and the sore be kept smeared simply with boracic ointment.

CHAPTER XXI.

WOUNDS OF THE EXTREMITIES—AMPUTATION.

Limitations of Conservation—Classification of Wounds possibly demanding Amputation—Duty in Doubtful Cases—*Period for Amputation*—Primary, Intermediary, and Secondary Periods defined—Effect of Antiseptics to prolong Primary Period—Shock a Contra-indication—Amputation to be done during Primary Period—*Point of Amputation—Treatment of the Amputation Wound.*

There remain for presentation some considerations as to the management of lacerated, contused, or gunshot wounds of the extremities in which the damage is so extensive as to compromise the vitality of the parts beyond the wound and to cause the question of amputation to be entertained. Interest centres about three points, viz.:—To what extent should attempts at conservation be pushed, and, if amputation is imperative, when and at what point should it be done?

Limitations of Conservation.—In deciding to what extent attempts at conservation should be pushed, two considerations must influence the surgeon. These are: 1. Can the vitality of the distal portions of the limb be preserved? and, 2. If preserved, will the limb be a useful member or a useless incumbrance?

For purposes of systematic consideration the wounds in question may be divided into five general classes, as follows:—

1. Injuries in which the whole mass of the limb, to a variable distance from its end, is mangled and pulpified, or torn nearly away.

2. Injuries in which, at a limited part of the continuity of a limb, all the tissues in its whole thickness have been crushed.

3. Injuries of less extent but in which the great vessels of an extremity have been lacerated.

4. Injuries characterized by open wounds communicating with extensively comminuted bones or with large joint cavities.

5. Injuries characterized by extensive stripping away of soft parts, as integument and muscles.

In the two first of these classes the duty of the surgeon is plain ; primary amputation must be performed ; but amputation in these cases is to be regarded less as a formal operation than as a part of the general procedure of the primary cleansing of the wound which requires that devitalized tissues shall be removed as perfectly and speedily as possible from every wound.

In the remaining three groups, the propriety of attempts at conservation must depend on the facilities at the command of the surgeon for preserving the wound from septic infection and securing to it perfect rest during repair, and upon the probable future usefulness of the part, if amputation is avoided. The mere wound of the great vessels, unless it be attended with such extensive laceration of the adjacent soft parts as to render the nutrition of the distal portion of the limb by the collateral circulation obviously improbable, does not call for immediate amputation. Wounds of the joint cavities and compound comminuted fractures, in the great majority of cases, can be conducted to recovery by adequate measures of disinfection, drainage, and immobilization. The extensive stripping away of soft parts, although ultimate cicatrization of the wound may be possible, may nevertheless be a sufficient cause in some cases, for primary amputation, on account of the deformity or uselessness of the part which would be left.

Cases will present themselves in which the question, whether the vitality of the distal portions of the limb can be preserved or not, must be a doubtful one, and will depend on the prevention of inflammatory disturbances in the wound, and in placing the endangered portion of the limb in conditions that shall favor its nutrition as perfectly as possible. It would be incumbent on the surgeon, in such a case, to make the effort at conservation, and to resort to amputation only when it had become plain that the efforts at protection were unsuccessful, or that the vitality of the endangered tissues was hopelessly destroyed.

Period for Amputation.—Wounds in which the accession of septic conditions is not prevented, have their history divided into three periods, *primary*, *intermediary*, and *secondary*, the primary being that short period which intervenes between the reception of the wound and the appearance of the secondary traumatic fever caused by the development of septic inflammation in the wound, a period generally of from thirty-six to forty-eight hours ; the intermediary period being the period during which progressive local inflammatory infiltration and general fever prevail, a period

extending over a variable time; the secondary beginning with the subsidence of the intermediary stage, as marked by limitation and diminution of the infiltration and free suppuration from the wound surfaces.

When adequate antiseptic measures are employed, the primary stage is indefinitely prolonged, inflammatory infiltration and secondary traumatic fever are prevented, and an opportunity afforded for the full display of the reparative resources of the injured part.

When the necessity of amputation is unquestionable, it should, if possible, be done before the supervention of the intermediary stage. If this has been impracticable, it should be deferred to the secondary period, unless progressive gangrene of the wound develop, when amputation, through tissues yet sound, should be done as quickly as possible. Amputation should never be done, in any case, until full reaction from the shock of the original injury has been secured, and, if such reaction is delayed until the primary stage has passed, the operation must be deferred yet longer, until the secondary stage has been reached.

The prolongation of the primary stage by antiseptic treatment—continuous antiseptic irrigation being the method which, in general, is best adapted to the treatment of these cases—makes it possible for the surgeon to delay amputation until such time as, in his judgment, the patient will be in the best condition to bear the operation. In some cases it will happily have served to demonstrate the possibility of recovery without amputation. In cases, the possibility of saving which manifestly depends entirely upon the success of the efforts to prevent their being invaded by septic infection, as soon as it is evident that these efforts have not been successful, amputation should be proceeded with before the full local and constitutional symptoms of the sepsis have developed.

Point of Amputation.—The choice of the point at which the amputation shall be made may be greatly influenced by the facilities at the command of the surgeon for keeping the wound asêptic. If these be adequate for the purpose, the section may be made at whatever point may be desirable to give the patient the most useful stump, even though bruised and lacerated parts be included in the flaps. These are preserved from inflammatory disturbance, their full vitality is regained, and they participate in the formation of the stump without disaster from sloughing. When, for any reason, the wound cannot receive adequate antiseptic treatment, amputation will, if possible, be made at a point sufficiently far above the injury to exclude all bruised and lacerated tissue from the flaps.

TREATMENT OF THE AMPUTATION-WOUND.—In the treatment of the wounds made by amputation, scrupulous attention should be paid to all the details of treatment which have been dwelt upon in the chapters on the "Practice of Wound-Treatment" in the first part of this work. Absolute aseptic cleanliness of everything—hands, instruments, dressings,—that is brought in contact with the wound; perfect arrest of hæmorrhage by catgut, cut short after being securely knotted; ample provision for drainage from the deepest recesses of the wound; thorough disinfection of the wound surfaces; careful apposition of the flaps by both deep and superficial sutures; protection, support, and compression by external antiseptic dressings; an elevated and comfortable position for the stump and protection of the limb from motion or external traumatism of any kind, these constitute the indications to be observed. The various means by which they may be met have been sufficiently pointed out. The adaptation of the particular agents to each special case must be left to the judgment of the surgeon.

INDEX.

ABERNETHY, on ligatures, 106
Abdomen, wounds of, 351
Abdominal viscera, protrusion of, 353
Abscesses, metastatic, 49
Absorbable drainage-tubes, 146
Absorbent cotton, 184
gauze, 186
Absorption of subcutaneous effusions, 238
Achilles-tendon, suture, 272
Acupressure, 99
in vein-wounds, 292
to compress vessels in their continuity, 125
Adhesion, union by primary, 27
union by secondary, 29
Adhesive gauze, 190
plaster, 162
Afflux, physiology of, 24
Age, modifying the effects of wounds, 13
AGNEW, D. H., on mediate ligation of an intercostal artery, 344
Air, both an antiseptic and a carrier of contagion, 18
exposure to, as an hæmostatic, 95
impure, effect of, on wounds, 18
of Paris, germs in, 39
purification, 66, 68, 156
varying degrees of purity of, in different localities, 66
ALBANESE, on penetrating incised wounds of the abdomen, 354
of the chest, 345
on treatment of incised wounds, 241
Albuminates, zinc and phenol, 81
Alcohol, hæmostatic effects of, 97
strength required to restrain germ-development, 72
ALLIS, O. H., on lateral ligation of internal jugular vein, 340
Alum, as an hæmostatic, 118
Alumina, acetate and aceto-tartrate, as antiseptics, 83
Aluminated charcoal, 192
Ammonium chloride as a sorbefacient, 239
AMUSSAT, on torsion, 115
Amputation, 375
Amputations, comparative table of septic and aseptic cases, 55
Amputation-wounds, treatment of, 378
Anæmia, from hæmorrhage, 129
Anæsthetics, parallel between, and antiseptics, 69
Anal region, micro-organisms infesting, 64
wounds of, use of aluminated charcoal in, 84
Aneurism, diffuse traumatic, 288
Animal ligatures, 108
Anodynes, 216
after hæmorrhage, 126
Anthrax infection from catgut, 78
Antisepsis, 61
Antiseptic bath for instruments and appliances, 155
dressings, 184
sprays, 67
tampons, 248
treatment, results of, 54, 57
Antiseptics, 69
definition of, 60
in erysipelas, 229
Anus, wounds of, 374
Apparatus for irrigation, 141, 222
Apposition, defects of, analyzed, 27
in wounds of abdominal parietes, 352

Apposition, in wounds of blood-vessels, 282
peritoneum, 353
of contused and lacerated wounds, 244
divided nerves, 273
divided tendons, 271
incised wounds, 241
wound-surfaces, 160
Approximation stitches, 165
Arrest of hæmorrhage, 93
Arsenic, power as a germicide, 73
Arsenite of potassa, power as a germicide, 71
Arteries, effects of torsion on, 116
wounds of, 280
carotid, 315, 337
intercostal, 344
internal mammary, 342
middle meningeal, 314
vertebral, 338
Artery forceps, 112
Asepsis, 60
how obtained, 61
Aseptic ligatures, 112
in vein-wounds, 293
sponges, 139
wounds defined, 11
Atmospheric organisms, causes of decomposition, 38
Auto-transfusion of blood, 129
AVELING, apparatus for direct transfusion of blood, 136
Axilla, micro-organisms infesting, 64
Axillary vein, lateral suture of, 298

BACILLI, 41
Bacteria, 41
Bandage, elastic, tourniquet, 124
Bandages, 197
adhesive, application of, 163
adhesive, objections to, 164
for the head, 318
in the treatment of inflammation, 220
plaster-of-Paris, 211
Bandaging, as a means of apposition, 161
Base of the skull, fractures of, 311
Bath, antiseptic, for instruments and appliances, 155
Bavarian splint, 208
Bead suture, 179, 182
BELFIELD, on effects of micro-organisms, 45
on the causes of septicæmia, 49
BELL, C., illustrations of trephining, 326, 328
BELL, JOHN, discourses on wounds, 4
BERGMANN, on the causes of septicæmia, 49
BILLROTH, method of dressing wounds, 200
on causes of septicæmia, 49
on suture threads, 167
on turpentine as an hæmostatic, 97
Birth, wounds during, 318
Bismuth cotton, 186
intoxication, 89
subnitrate of, as an antiseptic, 88
Bladder, protrusion of, 356
suture of, 373
wounds of, 369
Bleeding in head-injuries, 312
BLOCK, on resection of the lungs, 347
on surgical interference with the heart, 346
Blood, abstraction of, in inflammation, 225
Blood-clots, how disposed of, 31
when to be left undisturbed, 62
Blood-poisoning, 49
Blood-supply of inflamed parts, how interrupted, 225
Blood-vessels, wounds of, 280
BŒCKEL, E., on hypodermics of carbolic acid in erysipelas, 230
BOILLAT, experiments with zinc, and phenol albuminates, 81
Bone drainage-tubes, decalcified, 146
Boracic acid, as an antiseptic, 83
power as a germicide, 71
power in restraining germ-development, 72, 73
Borated cotton, 185
Borax (biborate of sodium), strength required to restrain germ-development, 72, 73
Bowels, micro-organisms infesting, 64
Brain, compression of, 312
wounds of, 315
BRAUN, on lateral ligation of veins, 296
BRIGGS, W. T., on trephining, 321
Bromine, power as a germicide, 73

BRUNS, P., on acetate of alumina for continuous irrigation, 228
on treatment of compound fractures, 257
BRUNS, VON, on carbolated gauze, 189
spoon curettes, 158
on wood-wool, 194
BRYANT, T., on iodine, 84
on torsion, 115
on treatment of punctured wounds, 246
Buffalo-tendon ligatures, 109
Bullets, removal of, 249, 252, 253
Button suture, 180

CAMPBELL, H. F., on ligation of artery of supply in treating inflammation, 226
Canula, tracheal, 335
Capelline bandage, 319
Capillary drainage, 148
Carbolated cotton, 186
gauze, 187
Carbolic acid, as an antiseptic, 76
hypodermics of, in erysipelas, 230
intoxication, 80
local irritation caused by, 79
lotions, 77
power as a germicide, 71
strength required to restrain germ-development, 72
volatility of, 79
Carbolic gauze, rapid deterioration of, 79
oil, 78
sprays, 67
Cardiac sedatives, 126
Caribou-tendon ligatures, 109
Carotid arteries, wounds of, 337
Carotid artery, internal, wounds of, 315
Catgut, anthrax infection from, 78
drains, 148
ligatures, 109
sutures, 168
Catheterization in wounds of the bladder, 373
Cautery, 118
Cell-germination, physiology of, 25
Cerebri, hernia, 317
Changes of dressings, 214
Charcoal, 192
CHASSAIGNAC, on drainage, 145
on ligation of veins, 290
CHAULIAC, GUY DE, on drainage, 144
CHEYNE, description of Lister's method of wound-dressing, 198
on carbolated gauze, 187
on different species of micro-organisms, 42
on "the protective," 196
results of antiseptic treatment, 57
Chicken-bone drainage-tubes, 147
CHIENE, on catgut drains, 148
Chloral hydrate, power as a germicide, 71
Chloride of zinc, as an antiseptic, 81
Chlorine, power as a germicide, 73
Chromicized catgut ligatures, 110
Cicatrization, physiology of, 26
Citric acid, power as a germicide, 71
Classification of compound fractures, 256
of gunshot wounds, 250
of wounds, 8
Cleanliness, of adjacent tissues, 64
scope of the term, 62
Cleansing compound fractures, 257, 258
contused and lacerated wounds, 243
gunshot wounds, 247
peritoneal cavity, 367
primary, of wounds, 62
wounds, 138
Cloth for plaster-of-Paris splints, 211
Clothing of surgeon, to be purified, 155
Coagulants, 118
Coal-ashes, 193
Coaptation stitches, 165
Coils, water, in inflammation, 223
Cold, application of, in the treatment of inflammation, 220
as an hæmostatic, 96
COLLIN, instrument for transfusing blood, 132
Collodion, 163
iodoform, 201
Compound fractures, 255
Compresses, cold, in inflammation, 220
hæmostatic, 98
materials for, 162
warm and moist, in inflammation, 225
Compression, as an hæmostatic, 97
in the treatment of inflammation, 219

Compression, in the treatment of wounds, 206
in wounds of blood-vessels, 282
of the brain, 312
of parent trunk to arrest hæmorrhage, 119
Constitutional conditions, as modifying the effects of wounds, 14
Constitutional effects of wounds, 21
Continuous suture, 174
Contused punctured wounds, 245
Contused wounds, 242
Contusions, 22
of the scalp, 302
of the skull, 308
Cooling coils, 224
COOPER, ASTLEY, on ligatures, 106, 109
Corrosive sublimate, antiseptic properties of, 74
power as a germicide, 71, 72
strength required to restrain germ-development, 72
Cotton wool, 184
Court plaster, 163
Cranial nerves, injuries to, 315
Cranium, injuries to, 307
Creosote, power as a germicide, 71
Cupping, in inflammation, 225
in subcutaneous injuries, 239
CZERNY, case of lateral suture of internal jugular vein, 298
Czerny's suture, 363

DAVY'S LEVER for compressing iliac artery through the rectum, 122
Dead tissue, how disposed of, 31
Decomposition a cause of inflammation, 36
causes of, 38
Deer-sinew ligatures, 109
Defects of apposition analyzed, 27
of nutrition analyzed, 28
of protection analyzed, 28
Defibrination of blood, 134
Definition of wounds, 7
DESAULT, on ligatures, 106
tampon of, 343
Diastasis of cranial sutures, 311
DIEFFENBACH, needle-holder of, 166
Digital compression of parent trunk to arrest hæmorrhage, 119
Disease, pre-existing, as modifying the effects of wounds, 15
Disinfection of skin, necessity for, 65
Disturbances of healing, relief of, 218
of repair, destructive, 33
Douches of hot water, as a sorbefacient, 239
Drainage, 143
artificial, 144, 151
capillary, 148
definition of, 63
in compound fractures, 259
natural, 143
of contused and lacerated wounds, 244
of incised wounds, 241
of peritoneal cavity, 367
of pleural cavity, 349
primary, 152
secondary, 153
tubular, 145
when unnecessary, 63
Drainage-tubes, 145
for empyema, 349
Dressings, antiseptic, 184
external, to be purified, 156
iodoform, of Billroth, 200
Lister's method, 198
of wound, defined, 66
subsequent, 214
turf-mould of Esmarch, 203
DUNCAN, JOHN, observations of impurities in the air, 67
DUPUYTREN, on ligation of veins, 290
DUROY, on iodine, 84
Dust, 38

EAR, wounds of, 330
Ears, micro-organisms infesting, 64
Effusions, subcutaneous, 238
Embryonic reversion of tissue, 26
Emmert's suture, 362
Emphysema, 348
Empyema, 348
ERICHSEN, on the effects of diet on the repair of wounds, 15
on effects of overcrowding, 19
on ligation of veins, 290
Erysipelas of the scalp, 305
treatment of, 228

ESMARCH, apparatus for transfusing by hydrostatic pressure, 134
on antiseptic use of corrosive sublimate, 75
on enlarging openings in calvaria, 325
on exposing wounded blood-vessels, 284
on plaster-of-Paris bandages, 211
the turf-mould dressing, 203
use of elastic bandage to compress blood-vessels, 125
Evaporating lotions, 221
EVE, P., on deer-sinew ligatures, 109
Experiments on effects of ligatures on repair of vein-wounds, 293
Exploration of abdominal cavity, 356
of gunshot wounds, 249, 252
Extremities, wounds of, 375
Exudation, physiology of, 25
Eye, wounds of, 330
Eyelids, wounds of, 330

FACE, wounds of, 330
FEHLEISEN, on micrococci of erysipelas, 44, 229
Femoral vein, lateral suture of, 298
Fenestrated plaster splints, 211, 265
Fever of reaction, 22
traumatic, 22
FIELDING, on silkworm-gut ligatures, 109
FISCHER, E., on naphthalin, 87
FISCHER, on wounds of the heart, 346
Flexion, forced, in treating inflammation, 226
to arrest hæmorrhage, 119
FLOURENS, on nerve-grafting, 278
Fluids, irrigating, 143
Fomentations, 225
Food, as modifying the effects of wounds, 15
Forceps, hæmostatic, 102
torsion, 117
Forcipressure, 100
in vein-wounds, 292
Four-tailed cap bandage, 320
FOWLER, G. R., on naphthalin, 88
in naphthalinated gauze, 190
Fox-tail-tendon ligatures, 109
Fractures, compound, 255
of nasal bones, 330
Fractures, of the skull, 309
Function, impairment of, 23

GAINE, A. D., Needle-holder of, 167
GAFFKY, on the relation of micro-organisms to septicæmia, 50
Gangrene, spreading, cause of, 45
treatment of, 227
Gaping, 23
Gauze, 186
bandages, 197
GÉLY, the suture of, 362
GENZMER, on entrance of air into intracranial sinus, 313
Germs, 38
Germ-development, strengths of various re-agents required to restrain, 72
Germicidal strengths of various re-agents, 71
GERSTER, A. G., on lateral ligation of internal jugular vein, 340
Glover's suture, 174
GLUCK, on neuroplasty, 278
Gold-beater's skin, 163
Grafting, nerve, 278
Granulation, healing by, 29
Granulation-polypi, intertracheal, 335
Granulations, 29
GREENE, W. W., on boracic acid, 83
GROSS, S. D., case of wound of internal jugular vein, 295
on after-treatment in cases of hæmorrhage, 126
on ligating a wounded artery, 283
GUILLEMEAU, on the use of the ligature, 105
Gunshot wounds, 247
classification of, 250
of abdomen, 357
of brain, 316
of chest, 345
of face, 331
of œsophagus, 336
of scalp, 306
GUSSENBAUER, the suture of, 363

HÆMORRHAGE after extraction of teeth, 331
arrest of, 93
deaths from, 280

Hæmorrhage, general considerations on, 24
intermediary, 285
in abdominal wounds, 351
in contused and lacerated wounds, 242
in gunshot wounds, 247
in incised wounds, 240
intraperitoneal, 359
into pleural cavity, 348
into trachea, 335
primary, 285
secondary, 287
subcutaneous, 237
Hæmostasis, spontaneous, how effected, 94
Hæmostatic forceps, 102
Hæmothorax, 348
Halter bandage, 319
HAMILTON, F. H., on continuous submersion in hot water, 142
on hot water as an hæmostatic, 96
Hands of surgeon, method of purifying, 154
Hare-lip suture, 175
Head, bandages for, 318
-net, 320
wounds of, 301
Healing by first intention, 27
by granulation, 29
by scabbing, 30
by second intention. 29
disturbed, means of relief, 218
Heart, wounds of, 346
Heat, reduction of, in the treatment of inflammation, 220
HEATH, C., case of laparotomy for wound of bladder, 371
Hernia cerebri, 317
of the lung, 347
HEWSON, ADDINELL, on the effect of the weather on wounds, 16
Honeycomb plaster splint, 266
Horse-hair drains, 150
sutures, 169
Hot climates, healing of wounds in, 16
Hot water douches, as a sorbefacient, 239
HUETER, on arterial transfusion, 136
on hypodermics of carbolic acid in erysipelas, 230
HUMPHREY, G. M., on the importance of wound-treatment, 3
HUNT, WM., views on micro-organism, 47
HUNTER, C. T., on hot water as an hæmostatic, 96
saw for removing plaster splints, 215
Hydrochloric acid, power as a germicide, 71
Hydrostatic pressure as a means of transfusing blood, 131
Hydrothorax, 348
Hygienic conditions, as modifying the effects of wounds, 15
Hyperæmia, active, physiology of, 24
Hypodermics of carbolic acid in erysipelas, 230

ICE-BAGS, in inflammation, 223
Ichthyocolla plaster, 163
Idiosyncrasy as modifying the repair of wounds, 12
Immersion, in inflammation, 222
Immobilization, 206
in compound fractures, and joint-wounds, 262
in gunshot wounds, 254
in inflamed wounds, 219
Impairment of function, 23
Impermeable envelope, external, 196
Incised wounds, 240
of the scalp, 303
Incisions, in the treatment of inflammation, 219
in inflamed punctured wounds, 246
Inflammation, causes of, 35
note as to use of the term, 28
of incised wounds, 242
of subcutaneous wounds, 240
pathology of, 34
treatment of, 218
Instruments, how purified, 155
Intention, union by first, 27
union by second, 29
union by third, 29
Intercostal artery, wounds of, 344
Intermediary hæmorrhage, 285
Interrupted plaster splints, 212, 266
suture, 174

Interruption of blood-supply to inflamed parts, 225
Intestinal wounds, suture of, 360
Intestine, protrusion of, 355
Intra-cranial vessels, wounds of, 313
Invaginated bandage, 161
Invagination suture of Jobert, 364
Iodine, as an antiseptic, 84
as an hæmostatic, 97
lotions, 84
power as a germicide, 71, 73
power in restraining germ-development, 72
Iodoform, as an antiseptic, 85
collodion, 201
cotton, 186
dressings, 200
gauze, 189
intoxication, 86
Iron, chloride of, power as a germicide, 73
tincture of, power as a germicide, 71
subsulphate, as an hæmostatic, 118
sulphate, power as a germicide, 71
power in restraining germ-development, 72
Irrigation, 141
continuous, of septic wounds, 228
cool, in inflammation, 221
fluids for, 143
of contused and lacerated wounds, 244

JAMESON, on ligatures of buckskin, 108
JOBERT, the suture of, 361, 364
Joints, wounds of, 255, 259
JONES, J. F. D., on hæmostasis, 106
Jugular vein, internal, wound of, 292, 295, 298, 339
Juniper, oil of, for catgut ligatures, 111
Jute, 191

KANGAROO-TAIL-TENDON ligatures, 109
KEATE, ligation of middle meningeal artery, 314
KEETLEY, on hot water as an hæmostatic, 96
KEITH, on drainage of peritoneal cavity, 368
Kidney, protrusion of, 356
KLEBS, experiments on suppuration and septicæmia, 45, 50
Knee-joint, antiseptic excisions of, by Stokes, 57
Knots, suture, 173
KOCH, micrococcus of gangrene in mice, 44, 50
on carbolic oil, 78
results of experiments with germicides, 72
KOCHER, anthrax infection from catgut, 78
on irrigation with dilute solutions of chloride of zinc, 82
on oil of juniper for catgut ligatures, 111
on plugging a wounded vertebral artery, 338
on secondary suture in treatment of wounds, 144
on subnitrate of bismuth, 88
KOEBERLÉ, on forcipressure, 101
KOENIG, case of excision of the sternum, 346
KOPFF, deterioration of carbolic acid dressing, 79
KÜMMELL, H., on aceto-tartrate of alumina, 84
on antiseptic use of corrosive sublimate, 75
on preparation and use of aluminated charcoal, 192
on spun-glass drains, 150
KÜSTER, on hypodermics of carbolic acid in erysipelas, 231

LACERATED wounds, 242
of the scalp, 303
Lacerations, 22
LANGE, F., case of tendon-suture, 272
case of lateral ligation of internal jugular vein, 340
LANGENBECK, case of wound of internal jugular vein, 295
effects of immersion of wounds in warm water, 143
on ligation of veins, 290
Laparotomy, explorative, for intraperitoneal wounds of bladder, 372
for wounds of abdominal viscera, 356
Larynx, wounds of, 333
Lateral ligation of veins, 295

Lateral ligature of internal jugular vein, 339
Lateral suture of veins, 298
Lead suture-buttons, 181
Leeches, in inflammation, 225
LEITER, tubes for water coils, 223
LEMAIRE, the first to employ carbolic acid in wounds, 76
LEMBERT, suture of, 360
LIDELL, on deaths from hæmorrhage, 280
on lateral ligation of internal jugular vein, 340
on wounds of the vertebral arteries, 338
Ligation of artery of supply, in treating inflammation, 226
of bleeding vessels, 104
of veins, 290
of vessels in their continuity, 126
technique of, 112
Ligatures, aseptic catgut, 110
aseptic silk, 112
in wounds of blood-vessels, 283
lateral, of internal jugular vein, 339
materials for, 107
substitutes for, 107
Lime, chloride of, known as a germicide, 73
Lint, 191
Lips, micro-organisms infesting, 64
LISTER, J., and carbolic acid, 76
case of lateral suture of axillary vein, 298
on catgut ligatures, 110
on drainage of peritoneal cavity, 367
on lead suture-buttons, 181
on method of dressing wounds, 198
on primary drainage, 152
on "protective" material, 195
results of antiseptic treatment, 54
use of spray to purify air, 67
LISFRANC, on ligation of veins, 290
LITTLE, results of antiseptic treatment, 57
Liver, protrusion of, 355
Local effects of wounds, 23
LÖFFLER, on the relation of micro-organisms to septicæmia, 50
Longitudinal sinus, wound of, 313
LOWER, apparatus for transfusion, 137
Lungs, resection of, 347
wounds of, 346

MAAS, on acetate of alumina, 83
MAC CORMAC, on compound fractures, 256
on drainage-tubes, 152
on gunshot wounds, 248
on horsehair drains, 150
on the preparation of plaster-of-Paris splints, 219
MACEWEN, on chicken-bone drainage tubes, 147
on horsehair drains, 150
results of osteotomies, 56
Macintosh cloth, 196
MALGAIGNE, on lateral ligation of veins, 296
Mammary artery, internal, wounds of, 342
MARCY, H. O., on animal ligatures, 109
Marine lint, 191
MARKOE, on "through drainage," 153
MARTIN, H. A., adhesive plaster, 162
rubber bandage, 197
MASON, L. D., method for fracture of nasal bones, 330
Massage, 239
MAUNDER, on ligation of artery of supply in treating inflammation, 227
MCSWEENEY, on silkworm-gut ligatures, 109
Median nerve, suture of, 275, 277
Mediate ligation, 105, 113
Meningeal artery, middle, wounds of, 314
Mental states, as modifying repair of wounds, 12
influence of, over body, 13
Mercuric bichloride, antiseptic uses of, 74
power as a germicide, 71, 72
power in restraining germ-development, 72
Metal sutures, 169
Micrococci, 41, 42
and suppuration, 46
Micrococcus-poisoning, 51

Micro organisms infesting various regions of the body, 64
relations of, to disease, 45
relations of, to wound-disturbances, 58
species of, 40
unaffected by carbolic-spray, 67
MILLER, on ligation of veins, 290
MIQUEL, experiments on the air of Paris, 39
Modifying influences, repair of wounds, 12
MONSEL, the salt of, 118
Moose-tendon ligatures, 109
MOSETIG-MOORHOF, on iodoform, 85
Mouth, wounds of, 332
Mucous orifices, wounds of, difficulty in preserving aseptic, 65
Muriate of ammonia lotion as a sorbefacient, 239
Muscles, wounds of, 269

NAPHTHALIN, as an antiseptic, 87
in erysipelas, 231
Naphthalinated cotton, 186
gauze, 190
oakum, 191
Nasal bones, fractures of, 330
Nationality, as modifying repair of wounds, 12
Neck, wounds of, 333
Necrosis, 34
Needle-holders, 166
Needles, acupressure, 99
for suturing, 165
NÉLATON, on wounds of internal mammary artery, 342
NELSON, S. N., on cloth fabric for plastic splints, 211
Nerve grafting, 278
suture, 274, 276
Nerves, cranial, injuries to, 315
wounds of, 273
Net for head, 320
NEUBER, on absorbable drainage-tubes, 146
on antiseptic uses of corrosive sublimate, 75
on iodoform, 87
on use of turf-mould, 192
Neuroplasty, 278
NICAISE, on neuroplasty, 278
NIGHTINGALE, FLORENCE, on the effects of sunlight, 17
Nose, micro-organisms infesting, 64
NUSSBAUM, antiseptic results obtained by, 55
on erysipelas, 229
on intestinal sutures, 364
Nutrition, defects of, analyzed, 28

OAKUM, 191
Occlusion, primary antiseptic, of gunshot wounds, 248
Œsophagus, wounds of, 336
OGSTON, A., on different species of micro-organisms, 41, 43
on micrococcus-poisoning, 52
on the relation of micrococci to suppuration, 46
O'HALLERAN, on healing of wounds, 5
OLLIER, on thrombosis of veins, 290
Omentum, protrusion of, 355
Open method of treating wounds, 144
Open wounds defined, 9
iodoform dressing of, 201
Opiates, 216
Opium after hæmorrhage, 126
Osmic acid, power as a germicide, 73
Osteotomy—Macewen's results in, 56
OTIS, G. A., on the use of sutures in wounds of the abdominal parietes, 352

PAGE, H. W., on suturing nerves, 275
PAGET, on exposure to air as a cause of inflammation, 35
on influence of age on effects of wounds, 13
Pain, 23
PANUM, on the causes of septicæmia, 49
on value of defibrinated blood for transfusion, 134
Paraffine paper, 197
PARÉ, at the siege of Metz, 20
on the use of the ligature, 104
PARK, R., on naphthalin, 88
on naphthalinated gauze, 190
PARKER, on wound of middle meningeal artery, 314
PARKES, C. T., case of wound of longitudinal sinus, 313
on lateral ligation of internal jugular vein, 340

Particles, germinal, 38
PASTEUR, Experiments with micrococci, 45
on relation of micro-organisms to septicæmia, 50
on causes of decomposition, 38
PAULY, case of tendon-suture, 272
PÉAN, on forcipressure, 101
Pelvis, wounds of, 369
Pericardium, wounds of, 346
Peri-neural suture, 276
Periphlebitis, 291
Peritoneal cavity, cleansing, 367
drainage, 367
exploration of, 359
transfusion, 137
Peritoneum, wounds of, 352
Peritonitis, 358, 369
PETIT, J. L., tourniquet of, 123
Pharynx, suture of, 337
wounds of, 336
Phlebitis, 291
PHYSICK, on ligatures of leather, 108
PILCHER, J. E., case of wound of internal jugular vein, 292, 340
Pin suture, 175
Pincetten, compressiv-, 101
Pins, acupressure, 99
PIROGOFF, lath-gypsum splint, 265
on ligation of veins, 290
Plaster, adhesive, 162
ichthyocolla, 163
Plaster-of-Paris, how prepared for use, 210
splints, 208
splints in compound fractures, 263
Pleuræ, wounds of, 344, 347
Plugging blood-vessels, means of, 114
Pneumonia, traumatic, 347
Pneumothorax, 348
Poisoned wounds defined, 10
Poisoning by bismuth subnitrate, 89
by carbolic acid, 80
by iodoform, 86
Polypi, from exuberant granulations projecting into trachea, 335
PONFINCK, on peritoneal transfusion, 137
Position, as a means of apposition, 160
as a means of rest, 205
in arresting hæmorrhage, 119
Position, in the treatment of inflammation, 225
Potassium iodide, power as a germicide, 71
permanganate, as an antiseptic, 76
permanganate, power as a germicide, 71, 72
Poultices, 225
Practice of wound-treatment, 91
Primary hæmorrhage, 285
Primary amputations, 377
PRINCE, D., on bead suture, 179
on continuous submersion, 142
Principles of wound-apposition, 183
of wound-treatment, 1
Probes, 253
Probing, 253
Protection, defects of, analyzed, 28
Protective, the, 195
Protrusion of abdominal viscera, 353
Ptomaïnes, 49
Punctured wounds, 245
of scalp, 303
Purification of air, 66, 68, 156
of sponges, 139
Pus, 30
Putrefaction-producing organisms, 42
Pyæmia, 49

QUILL suture, 177
Quinine, power as a germicide, 73

REACTION, 21
Rectum, aluminated charcoal as a dressing after extirpation of, 84
wounds of, 374
Reef-knot, 173
Relaxation of vessels in treatment of inflammation, 224
of wounded structures by position, 160
stitches, 165
Removal of plaster splints, 213
Repair, destructive disturbances of, 33
modified normal, 29
normal, power of, 33
of wounds, modifying influences, 12
of wounds of blood-vessels, 281
Resolution of inflammation, 34

Rest, 205
after incised wounds, 242
in inflamed wounds, 219
Reversion of tissue, embryonic, 26
REYHER, on exploring gunshot wounds, 249
Ribs, resection of, 348
RICHARDSON, on iodine, 84
ROCHARD, on healing of wounds in hot climates, 17
Roller bandages, 161, 162
double-headed, for head, 318
plaster-of-Paris, 211
ROUX, on ligation of veins, 290
Rubber bandages, 197
in treatment of inflammation, 220
cord tourniquet, 125
tissue, 197
tubing for water-coils, 223

SAGITTAL bandage, 319
Salicylated cotton, 185
Salicylic acid as an antiseptic, 82
power as a germicide, 71
power in restraining germ-development, 72
Sand as a wound-dressing, 193
SANDS, H. B., antiseptic results of, 56
needle-holder of, 167
on iodoform, 85
on trephining, 309, 320
Saw-dust as a wound-dressing, 194
Scabbing, healing by, 30
Scalp, micro-organisms infesting, 64
wounds of, 302, 306
Scarifications of inflamed tissues, 225
SCHAPPS, J. C., case of penetrating gunshot wound of abdomen, 357
SCHEDE, case of lateral suture of femoral vein, 298
table of amputations, 55
Sciatic nerve, suture of, 277
Scrotum, micro-organisms infesting, 64
Secondary amputations, 377
hæmorrhage, 287
suture, Kocher's method of, 144
Sepsis, what constitutes, 60
Septicæmia, 49
treatment of, 232
Septic wounds defined, 11
how cleansed, 157
Serres-fines, hæmostatic, 101
Serres-fortes, hæmostatic, 101
SEUTIN, plaster shears of, 215
SHARPE, on ligatures, 106
Shock, 21, 128
Silk ligatures, how made aseptic, 112
for sutures, 167
Silkworm-gut ligatures, 109
sutures, 168
Silver wire sutures, 170
SIMON, on suture-threads, 167
SIMPSON, J. Y., on acupressure, 99
SIMPSON, I., case of penetrating wound of abdomen, 354
SIMS, J. M., on silver wire sutures, 170
on suturing peritoneal wounds, 353
on treatment of gunshot wounds of peritoneal cavity, 359
Sinus, wound of longitudinal, 313
Sinuses, intracranial, wounds of, 313
Skin, method of purifying, 154
precautions in disinfecting, 65
regions of, abounding in micro-organisms, 64
Skull, contusions of, 308
fractures of, 309
Sloughs, 32
Sodium, sulphite, hypo-sulphite, borate and salicylate, power as germicides, 71
Sorbefacients, 239
Spanish windlass, 124
Spleen, protrusion of, 355
Splints, 206
plastic, in compound fractures, 263
Sponges, 139
compressed, in the treatment of inflammation, 220
Spray, how most effective, 157
producers, 156
Sprays, antiseptic, 67
Spun-glass drains, 150
STEIN, A., on advantages of laparotomy in intra-peritoneal wounds of bladder, 372
STERNBERG, G. M., experiments with germicides, results of, 70
STIMSON, L. A., observations on antiseptic value of carbolic spray, 67
STOKES, antiseptic results of, 56
Stomach, protrusion of, 356

Strangulated intestine, 355
STRICKER, on repair of wounds, 25
Styptics, 118
Subcutaneous effusions, 238
hæmorrhage, 237
wounds, 237
Sublimated cotton, 186
sand, 193
Submersion, continuous, 142
Sulphuric acid, power as a germicide, 71, 73
power in restraining germ-development, 72
Sulphurous acid, power as a germicide, 73
Sunlight, effect of, on the wounded, 17
Suppuration, 30
and micrococci, 46
Surgical knot, 173
Suspension of splints, 213
Suture, bead, 179
button, 180
continuous, 174
Czerny's, 363
Emmert's, 362
Gély's, 362
Gussenbauer's, 363
interrupted, 174
invagination, Jobert's, 364
Jobert's, 361
Lembert's, 360
of bladder, 373
of intestine, 360
of nerves, 274, 276
of peritoneum, 353
of pharynx, 337
of stomach, 360
of tendons, 271
of trachea, 333
of veins, lateral, 298
peri-neural, 276
pin, 175
quill, 177
tubular nerve, 278
Sutures, application of, 165, 170
aseptic, 112
in wounds of abdominal parietes, 332
materials for, 167
removal of, 174
Syphonage and horse-hair drains, 150
Tampon of Desault, 343, 344
Tampons, antiseptic, 248
hæmostatic, 98
Teeth, hæmorrhage after extracting, 331
Tenaculum, 112
Tendo-Achilles, suture of, 272
Tendon-suture, 271
Tendons, wounds of, 270
Tension, effect of, 28
Thermometer, as a guide in the treatment of wounds, 216
THIERRY, on torsion, 115
THIERSCH, bead suture of, 182
on salicylic acid, 82
Thoracentesis, 348
Thoracic duct, wounds of, 344
Thorax, drainage of, 349
wounds of, 341
THORNTON, KNOWSLEY, on drainage of peritoneal cavity, 368
Thread for sutures, 167
Through-drainage, Markoe's method, 153
TIEGEL, experiments on suppuration and septicæmia, 45
TILLMANS, on hypodermics of carbolic acid in erysipelas, 231
on suturing nerves, 274
Toes, micro-organisms infesting, 64
Torsion, 115
Torsion-forceps, 117
TOURDES, on wounds of internal mammary artery, 342
Tourniquets, 123
Tow, 191
Towels, to be purified, 155
Trachea, suture of, 333
wounds of, 333
Tracheal canulas, 335
Transfusion of blood, 129
Traumatic fever, 22
TRAVERS, B., on wounds of veins, 289
Trephining, 320
Tropical climates, healing of wounds in, 17
TROUSSEAU, on fatal phlebitis after venesection, 290
Tubes, drainage, 145
Tubular drainage, 145
nerve-suture, 278
Turf-mould as a wound-dressing, 191
dressings of Esmarch, 203
Turpentine, hæmostatic effects of, 97
power as a germicide, 73

Turpentine, use in disinfecting skin, 65
Twisted suture, 175
TYNDALL, researches on causes of decomposition, 38

ULNAR nerve, suture of, 275
Union of wounds, 25

VASCULAR relaxation, means of producing, to relieve inflammation, 224
VAULAIR, on tubular nerve-suture, 278
Vein, internal jugular, wounds of, 339
Veins, lateral ligation of, 295
lateral suture of, 298
wounds of, 288
VELPEAU, on torsion, 115
Venesection in head-injuries, 312
Ventilation, necessity for, 18
VERNEUIL, on forcipressure, 101
Vertebral arteries, wounds of, 338
Vessels, intra-cranial, wounds of, 313
VINCENT, on advantages of laparotomy in intra-peritoneal wounds of bladder, 372
VOLKMANN, anthrax infection from catgut, 78
antiseptic results of, 54
spoon-curettes of, 158

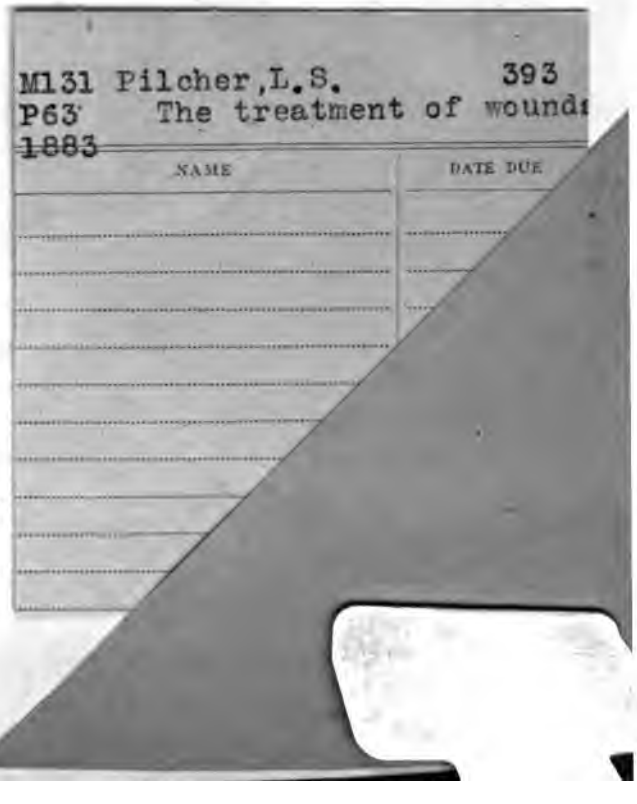
WALES, P. S., on healing of wounds in hot climates, 16
WALTER, case of intra-peritoneal wound of bladder, 370
Water-coils, in inflammation, 223
Water, hot, as an hæmostatic, 96
Waxed-paper, as a wound-dressing, 197
Weather, effect of, on repair of wounds, 16
WEIR, R. F., on antiseptic uses of corrosive sublimate, 75
on deterioration of carbolic acid dressings, 79
WELLS, SPENCER, on drainage of peritoneal cavity, 368
on forcipressure, 101
WHITE, on horse-hair drains, 150
WIGHT, J. S., artery forceps, 117
on wire-gauze splints, 207
WILLETT, A., case of laparotomy for intra-peritoneal rupture of bladder, 371
Windows in plaster splints, 211
Wire-gauze splints, 207
WISEMAN, R., definition of wounds, 7
Wood-wool, as a wound-dressing, 194
Wound-disinfection, 69
disturbances and micro-organisms, 58
dressings defined, 66
dressings, Lister's, 198
secretions, importance of preventing their accumulation, 63
Wounds, aseptic, defined, 11
classification of, 8
communicating with bone-fractures, or opening joint-cavities, 255
constitutional effects of, 21
contused, 242
definition of, 7
gunshot, 247
incised, 240
lacerated, 242
open, defined, 9
open, effects of inflammation in, 36
of mucous orifices, difficulty in preserving aseptic, 65
of special regions, 299
poisoned, defined, 10
septic, defined, 11
septic, how cleansed, 157
physiology of repair of, 25
punctured, 245
special, 235
subcutaneous, 237
subcutaneous defined, 9
suppurating, 30
WRIGHT, D. F., on ligation of artery of supply in treatment of inflammation, 226
Wrist, case of incised wound of, 241

YOUNG, THOS., on ligatures of catgut, 108

ZAHN, experiments on suppuration and septicæmia, 45
ZEIS, effects of immersion of wounds in warm water, 143
Zinc, chloride of, as an antiseptic, 81
power as an application to septic wounds, 159
power as a germicide, 71
sulphate, power as a germicide, 71
ZWEIFEL, anthrax infection from catgut, 78

LANE MEDICAL LIBRARY

To avoid fine, this book should be returned on or before the date last stamped below.


M131 Pilcher, L.S. 393
P63 The treatment of wounds
1883
NAME
DATE DUE

COOPER

MEDICAL COLLEGE